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Improving the Physical Fitness of Youth

A Report of Research in the Sports-Fitness School of the University of Illinois

THOMAS KIRK CURETON

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Monographs of the

SOCIETY FOR RESEARCH IN CHILD DEVELOPMENT

SERIAL NO. 95, 1964 VOL. 29, NO. 4

Improving the Physical Fitness of Youth

A Report of Research in the Sports-Fitness School of the University of Illinois

THOMAS KIRK CURETON*

assisted by

ALAN J. BARRY

University of Illinois

* Department of Physical Education for Men, University of Illinois, Champaign 61822.

Dedicated to the 2,400 parents who have cooperated so well in this study, and to the managers, Dr. A. C. Moore and Thomas F. Krizan, and head instructors, Jesse C. MacLeay, T. F. Krizan, Michael L. Pollock, and Frederick B. Roby, who managed and led much of the practical work of instruction and organization

PREFACE

This monograph represents an accumulation of research evidence based upon 11 years of experimentation with young boys in the Sports-Fitness Summer Day School, sponsored by the College of Physical Education, University of Illinois, in Urbana. Test folders have accumulated from testing about 1,200 boys twice, once at the beginning and once at the end of the summer course of eight weeks. During two years the tests were repeated one week apart to check the reliability of the tests as administered to young boys. The basic data are in the files of the Physical Fitness Research Laboratory, Huff Gymnasium, University of Illinois, and for the main part are also reported in 39 theses for the M.S. and five dissertations for the Ph.D. in Physical Education, done under the supervision of the senior author, and available in the library of the University of Illinois, in Urbana (listed in Appendix D). We have attempted to write up the work as a whole and to point up its meaning for understanding the nature of and methods for improving the physical fitness of young boys. While there is a national sentiment that such improvements should be made, what this actually means in methodology within or without physical education has not been faced very realistically in terms of curriculum or leadership.

It is very clearly indicated in this study that the usual program of basic instruction in sports and games is apt to fall short of developing physical fitness compared with what is wanted. The studies reported herein examine the relative value of ordinary types of games and sports instruction contrasted with various types of endurance training, dietary supplementation, and the use of motivating tests and individualized guidance in follow-up work throughout the year. Conferences with the parents of each boy have enabled the staff to introduce points of information and to point up certain emphases relative mainly to the endurance ingredient in the program, which is all too frequently lacking.

The repetitious conferences with the parents from year to year, with the matching of each boy against the various tables for each age, have brought about a higher level of understanding than is usually possible, as this procedure has resulted in parents contacting the instructors and laboratory research workers to study the results of the various tests and ratings. It is felt that some contribution to motivation has been made by this method.

The program was initiated in 1950 by the senior author, as an extension of the work of the Physical Fitness Research Laboratory, after a background of more than 10 years of work with boys in camps. Some preliminary ex-

periences in the Champaign-Urbana area made it plain that an extensive endurance type of experimental program could not be conducted in the public schools. We were willing to take the responsibility for an endurance-type program, but the schools were not. It should be emphasized that the main goal was to find a way to develop the stamina in the youth along with the full cooperation of the parents. After 11 years our perspective is that parents have been only too willing to cooperate, the tradition of the "sports pattern" of program being the greatest barrier to developing endurance. As interesting as softball is, for example, it does not develop stamina. It has never been the intent to de-emphasize any of the sports, nor to eliminate them, but to add more endurance work for the sake of fitness. It is probable that better endurance has made some of the activities more enjoyable. In the public school setting numerous inhibitors are noticeable: (a) fears of overtaxing or hurting the child; (b) the preconceived type of games and play program; (c) lack of sufficient time for teaching or testing; (d) lack of interest on the part of teachers not trained to conduct activity work; (e) lack of testing equipment, laboratory space and facilities, as well as leadership for human biological types of investigation.

Our project has developed into a first-class investigation-demonstration type of school, considered of great value to graduate students in physical education, health education, and recreation. The laboratory teaching-testing approach has enabled the young boys to relate specific fitness tests and measurements with sports and health. The boys have usually been able to make connection between a fitness component as tested and the use of that quality in a sport or in live situations. It is quite feasible to teach many aspects of health and fitness in the combined laboratory-field-pool-gym-camp setting. This has always depended upon having competent leaders.

Among those who have worked on the staff and made some of the measurements in various years are the following: Alan J. Barry, Edmund M. Bernauer, Patrick J. Bird, James S. Bosco, James L. Breen, Beulah J. Drom, Stanley R. Brown, Eugene V. Doroschuk, Robert B. Eynon, Mary D. Gray, John E. Greenleaf, William L. Haskell, Robert E. Herron, Richard A. Holmes, Annelis S. Jensen, Ray O. McClung, Charles E. Larson, Jesse C. MacLeay, Richard D. Marsh, Grace E. Matz, Robert E. McAdam, Joseph Guy Metevier, Paul A. Mole, George C. Moore, Richard J. Mulvihill, William A. R. Orban, William L. Penny, Everett E. Phillips, Michael L. Pollock, John T. Powell, Frederick B. Roby, Jr., Josef Ruys, Roland L. Ryan, James S. Skinner, Leroy F. Sterling, Karl G. Stodefalke, Wayne D. Van Huss, Harold P. Wells, and James N. Wright, Jr.

About 50 graduate students have contributed to some part of the data included, and all are cited in the footnotes in the particular chapters where their material has been used. A list of the 41 graduate theses is given in Appendix D, these being specifically part of the project.

The plan of the write-up has been to relate the work done in our own experimental school to the status and needs of the country as a whole, to review the known experiments related to improving the fitness of youth, and to provide tables and graphs of a wider array of fitness tests and measures than is usually available. The data have already been used with teacher groups and in the interests of the President's Council on Youth Fitness. It may be viewed as adding knowledge to an area where very little precise knowledge has been available and the procedures for fitness education early in life quite incidentally arranged or ignored.

THOMAS KIRK CURETON, JR.
Senior Author

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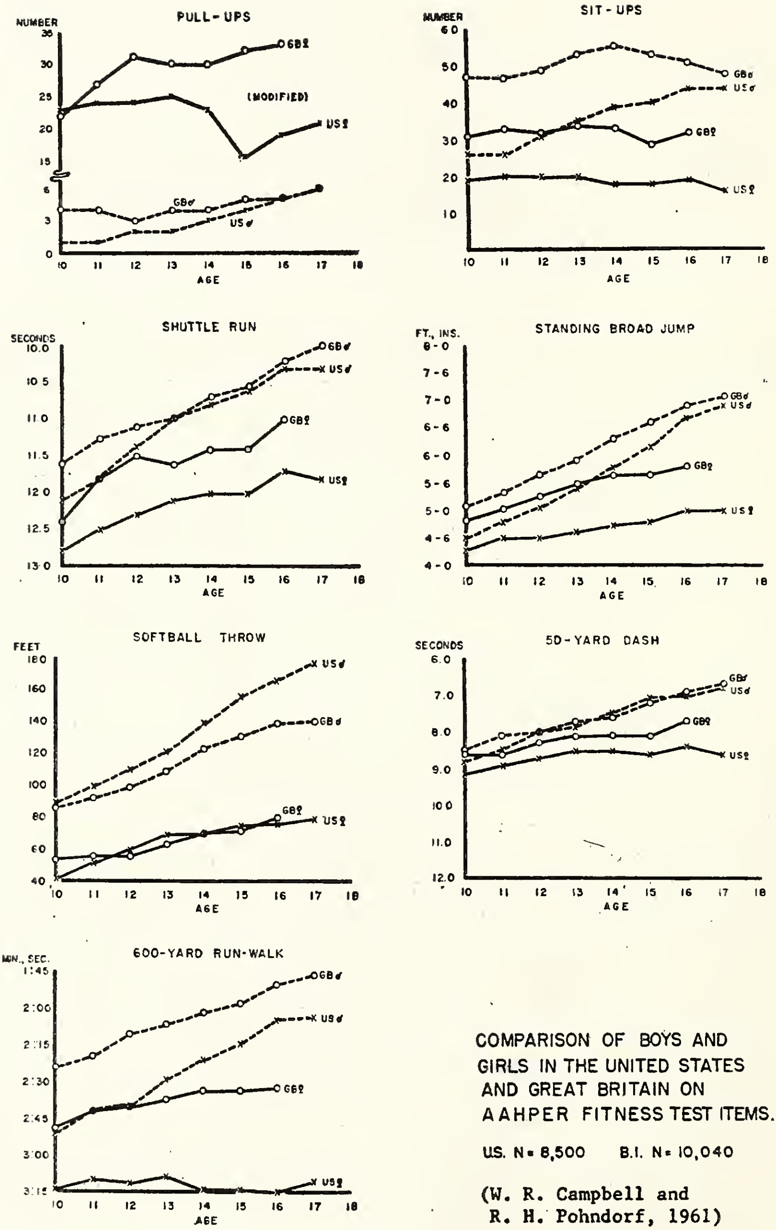
I

THE PHYSICAL FITNESS STATUS OF AMERICAN YOUTH AND THE DEVELOPMENT OF CORRELATIVE PROGRAMS IN PHYSICAL EDUCATION

Current interest in youth fitness stems from a well-founded awareness that the youth of America are inferior in several basic areas of physical fitness compared with children in western Europe. That this interest should find expression in peacetime distinguishes it clearly from similar trends observed during World Wars I and II and serves to free it from much of the emotion and jingoism normally coincident with wartime movements. The Kraus-Weber tests of minimum muscular fitness, administered to children in the United States, Switzerland, Austria, and Italy, and first reported in 1953 (94, 95), revealed marked deficiencies in strength and flexibility in American children as compared with samples of European children. The tests used were heavily criticized for failing to distinguish sufficiently between "fit" and "unfit" children, and for the undue emphasis placed on one of the test items (a flexibility test) which accounted for the largest number of failures (20, 61, 127).

In 1957 the American Association for Health, Physical Education and Recreation sponsored a national survey of the physical fitness of American boys and girls aged 10 to 17 years, using a more adequate battery of tests. The results of this 1957 survey, based on a sample of 8,500 boys and girls, were reported and distributed in booklet form (72, 73, 74). The same tests used in 1957 were subsequently administered to 10,040 British boys and girls of similar age, by Campbell and Pohndorf, wherein it was shown that the British boys and girls were superior to American boys and girls in all areas of fitness measured except the softball throw for distance (21). The British boys were found to possess greater shoulder girdle strength (pull-ups), superior agility (shuttle-run test), better abdominal endurance (sit-ups), more leg power (standing broad jump and 50-yard dash) and higher levels of circulatory-respiratory fitness (600-yard run-walk). In addition, the British girls were superior to American boys at ages 10, 11, 12, and 13 in five of the seven test items (Figure 1). Similar results were also obtained in the city of East London, South Africa, where the same test battery was administered to 500 boys and 500 girls, aged 12 to 16 years, by Johnstone and Haig, respectively (63, 79, 81).



COMPARISON OF BOYS AND GIRLS IN THE UNITED STATES AND GREAT BRITAIN ON AAHPER FITNESS TEST ITEMS.

US. N = 8,500 B.I. N = 10,040

(W. R. Campbell and R. H. Pohndorf, 1961)

FIGURE 1

The results shown in Figure 1 reveal several interesting points:

1. American girls deteriorate very badly in upper body strengths (pull-ups) after 14 years of age, in sharp contrast to British girls, who continue to improve. This reveals either a lack of incentive or the lack of an adequate program of gymnastics, as American girls do not "train" but play games and participate in dances.

2. Abdominal and thigh flexor muscular endurance does not improve in boys either in the United States or Great Britain (Figure 1). This also may reflect a general dependence upon games rather than straightforward conditioning exercises, such as sit-ups and leg-raising exercises.

3. The 600-yard run-walk does not improve in American girls from 10 to 17 years, whereas it does improve slightly among British girls and considerably among both British and American boys.

Japanese physical education has long emphasized required jiujitsu (judo) throughout all of the school years, beginning at the elementary school level and continuing throughout the secondary school level. Observation of this program by Cureton, in Tokyo, showed this program to be strong in endurance, strength, and ability. Bouts for boys in training lasted 40 minutes on a virtual nonstop basis. Baseball was widely played as an out-of-school recreational activity but was always secondary to judo. Swimming instruction received national emphasis during the summer months.

Yoshiyuki Noguchi (120a) reported tests of fitness on Japanese children in 1956. After demonstrating with a large sample of children that Japanese youth were superior to American youth in endurance, strength, and flexibility, Noguchi concluded that "the danger was now in Japanese youth losing their fitness by trying to live like American youth."

Some Steps Already Taken to Develop Physical Fitness in the United States

The results of these comparisons stimulated educational, professional, and governmental bodies to action in various forms. These developments may be summarized as follows:

1. Stimulated by President Eisenhower's Youth Fitness Council and the Citizens' Advisory Committee, hundreds of articles have been published by newspapers and magazines on matters of youth fitness. These have been directed, in general, to the lay public and represent the most widespread publicity ever received by physical education. Dr. Shane McCarthy "stumped the country" in the interest of this program as its executive director.

2. Follow-up testing has been carried on in hundreds of schools in cooperation with "Operation Fitness" of the Association for Health, Physical Education and Recreation, using the following tests: sit-ups, pull-ups, shuttle run, standing broad jump, 50-yard dash, softball throw for distance, and 600-yard run-walk.

3. Twenty-nine governors created State Youth Fitness Councils or Advisory Committees and many promotional meetings have been held from 1957 to date.

4. The national conventions of the American Association for Health, Physical Education and Recreation over the past six years (1957, Chicago; 1958, Kansas City; 1959, Portland; 1960, Miami Beach; 1961, Atlantic City; 1962, Cincinnati) dwelt heavily on the physical fitness need but almost ignored the methods needed to produce fitness. Most of the teachers and leaders have assumed that more of what is already too poor will remedy the situation. The physical education in the public schools has never been organized to develop stamina in youth. Approximately 50 per cent of the public schools have no regular physical education instruction in the elementary grades. Many teachers' institutes have listened to speakers on fitness but participation has been lacking.

5. The American Amateur Athletic Union established a National Fitness Committee, developed a battery of physical-fitness tests, and conducted competitions in all AAU districts of the United States for both boys and girls.

6. The 4-H Clubs, active along these lines for many years in rural areas, continued their testing programs. The University of Illinois (Dr. D. M. Hall) developed a *Youth Fitness Manual* (66). Several reports of tests given in Illinois were published.

7. The Junior Chambers of Commerce initiated "Junior Olympics" in many cities, usually in collaboration with the YMCAs.

8. The American College of Sports Medicine drew up and publicized widely a "Bill of Rights" for American children (130).

9. The American Association for Health, Physical Education and Recreation inaugurated "Operation Fitness, USA" and sold to schools many thousands of test booklets, emblems, and badges designed to stimulate interest in the development and maintenance of physical fitness.

10. The American Medical Association published "The Seven Paths to Fitness" (3) and "Medical Aspects of Sports" (2), and commended the founding of the American College of Sports Medicine, devoting in 1956 an entire issue of their journal to physical-fitness work (83). This has been followed by a 1958 pamphlet entitled "Exercise and Health" (12). Doctors have endorsed the fitness campaign.[1]

11. Considerable extension of adult physical fitness work has occurred in the United States with the YMCAs offering at least 300 clinics to the public, graduate seminars in dentistry offering physical fitness lectures and demonstrations, and many faculty groups taking up fitness work at noon or in the late afternoon or evening. Schools have begun offering extension

[1] There is much evidence of this among dentists, pediatricians, orthopedic surgeons, and physical medicine doctors. There are more writing, more serving on committees, and more taking part themselves in adult fitness work.

courses for adults in the evening, and various executive or professional groups have sought special education in this area.[2]

12. Sports-medical groups have featured the presentation of scientific data on exercise in relation to adult fitness. Among the best efforts in this area are the Colloquium on *Exercise and Fitness* (148) at the University of Illinois in 1960, and the World Seminar in Health and Fitness (102) at Rome in 1960. Both of these reports have been widely circulated by the Athletic Institute of Chicago.

13. President John F. Kennedy's Youth Fitness Council, including several cabinet members of the United States Government, published in the fall of 1961 a booklet, *Youth Fitness* (138), calling for 15 minutes of continuous exercise to be given daily in every grade school of the United States and listing illustrative exercises. Many lines of publicity were stimulated in magazines, newspapers, and conventions of medicine, health, physical education, and recreation. A new era of emphasis on physical fitness in American life is now under way.

President Kennedy stimulated great interest with his personal article on "The Soft American" in *Sports Illustrated* on December 26, 1960, calling for a minimum of 15 minutes of continuous exercise to be given in every grade school of the United States and listing illustrative exercises.

14. Various projects have been developed in physical education research centers, such as those at Springfield College, the Physical Fitness Research Laboratory at the University of Illinois and at the University of Michigan, in an attempt to analyze the fitness contribution of American physical education. Certain laboratories attached to experimental schools of education and medicine (as at Lankenau Hospital, Philadelphia) have expanded their efforts to throw light upon this situation.

It should be noted that the surveys of fitness were made in cities where programs of physical education exist; it is also true that about half of all American towns have no organized physical education program under trained leadership (137). While the need is for balanced educational programs in health, physical education, recreation, and safety, the recommended programs are virtually devoid of any type of systematic endurance training such as would normally occur in swimming, skating, cycling, rowing, or running—stamina types of training (67, 112, 131).

Brief Historical Development of Physical Education in the United States

These contemporary developments in the area of physical fitness should be viewed in perspective by noting the several types of programs which

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[2] This work began in 1946 at the University of Illinois as an experimental program of adult fitness, centered in the Physical Fitness Research Laboratory, under the direction of T. K. Cureton. It is so cited in a NEA release from Washington, D.C., June 1, 1962.

have markedly affected the growth of physical education in the United States.

Physical education in the United States was, in the first place, mainly *gymnastics* (Swedish corrective gymnastics and German apparatus gymnastics, followed by Danish free rhythmical conditioning gymnastics, 1820–1899).

The next emphasis in physical education was on English *games;* and these were augmented by the American-invented games of basketball, baseball, football, and volleyball (1900–1920).

Competitive football, basketball, track and field, baseball, wrestling, tennis, fencing, swimming, and gymnastics developed in the colleges as "Athletic Association" sports; and the high schools and junior high schools in imitation adopted them in a similar pattern; elementary schools adopted the elements of such games as physical education. These sports are usually administered apart from required physical education (1885 to the present) and are also taught in required physical education classes. It seems certain that physical education relinquished too much of its basic developmental and conditioning work for fitness in the urge to "play." In fact, "Throw out the ball" too frequently supplanted systematic progressive physical training.

Physical education was profoundly influenced by World Wars I and II as some physical fitness activities became imperative (calisthenics, forced marches, fitness tests, swimming, military drill, etc.) and other "training" activities were introduced into the programs for survival and fitness. In accord with the needs of the times, there arose the specialized areas of *survival aquatics* (conditioning in the water to combat fatigue, cold, and long immersion), skin diving and SCUBA (underwater swimming without and with compressed air tanks, respectively). Several very solid conditioning manuals were developed (30, 32, 49).

Many forms of *dance* (folk, basic rhythms, and tap, square, social, acrobatic, modern) became prominent in women's physical education (1930 to the present), and basic rhythms and dances were introduced into the grades.

Tests of physical fitness and skill developed after 1928 for classification and guidance purposes. Subsequent research has since endeavored to determine the persistent changes which each type of activity can make over weeks, months, and even years of sports fitness work. It is evident that such changes need to be evaluated not only in terms of performance in skills but also in terms of personality, circulatory, respiratory, metabolic, nutritional, and physical development (physique) effects. Equally apparent is the fact that a good beginning has been made in *understanding* the effects of persistent exercising throughout life upon the energy levels, glandular functioning, personality components, physiological aging, resistance to stress, disease, and accidents (17, 115). Careful, systematic investigation of these aspects will continue in the future.

Ferenc Hajdu (64) (Hungary) points out that physical education is responsible for the development of certain qualities like health, strength, and beauty, and also disciplines such as promptness, endurance, skill, and courage. The increased dependence of American physical education on competitive games to develop these qualities is very obvious, but the result has been that only a small part of the student body gets this program, and now even the sports are viewed as inadequate to deal with all types of fitness problems. The European system, which has been found both effective and economical, is in sharp contrast by requiring a full hour per day of gymnastics for several years. The American system is to copy the athletes as soon as possible (1).

There is now a trend to reactivate more adequate training and conditioning programs in the high schools (32, 142, 156).

Scientific Studies of Working Capacity

Serious investigation of the physical working capacity of children has been under way in Sweden and in the United States (8, 69, 134). These studies, in terms of oxygen intake capacity (converted to energy capacity), show the average of Swedish children to be higher than that for American children of the same age.

Physical education has approached working capacity in the same terms but, because of the number of subjects usually involved, the *length of time* a person can last in a given exercise is usually preferred, because of its simplicity and economy. Twenty-eight such muscular endurance exercises were studied in 1945 (49). The present study does most of this same work with young boys, develops norms of performance in the 600-yard run, push-ups, bar dips, sit-ups, hops, chinning, and treadmill run events.

The prediction of treadmill all-out run time was carried out in this work as a contribution to understanding small boys while performing such endurance events of an "all-out" nature. Scientific analysis has been made to show that the "all-out" treadmill run is influenced as much by basic neuromuscular ability (vertical jump, agility, and leg strength) as by oxygen intake (55). The fact remains always in view that neither the boys nor their parents are interested in oxygen intake capacity but in what the boys can do. Oxygen intake capacity also fails to evaluate or delineate many of the specific types of neuromuscular abilities essential to effective use and protection of the body: balance, flexibility, agility, strength, power, and types of muscular endurance. The physiologists' view of "physical ability" has always been inadequate to the physical educator, who is interested in the many specific abilities rather than in general work capacity alone.

University of Illinois

SPORTS-FITNESS SUMMER DAY SCHOOL for boys 7 to 14

Urbana Campus, 8 weeks
from June 15 to August 6, 1964*

THE ACTIVITIES

Aquatics. This activity consists of instruction in beginning swimming, advanced swimming, diving, and lifesaving. Instruction and standardized tests are given in the Men's Old Gymnasium Pool.

Gymnastics and posture training. These activities include instruction in apparatus, tumbling stunts, trampoline, and posture training.

Track and field. Instruction is offered in the high jump, broad jump, shot-put, and the dashes.

Conditioning activities. Calisthenics, medicine ball drills, relay games, and running games such as soccer are included in this area.

Camping. One weekend overnight camping trip for the boys and their fathers is held at the Lake of the Woods about halfway through the summer session.

Endurance. Accumulative mile-athon.

* Adapted from 1964 brochure.

THE LABORATORY

Each boy spends four to five mornings (9:00 to 12:00) during the eight weeks at the Physical Fitness Laboratory in Huff Gymnasium.

The program in the laboratory consists of fitness testing and viewing specialized sports and physical fitness movies. Data are carefully recorded, scored, plotted, and graphed in terms of individual profiles. Individual interpretations are made to the boys and parents.

THE PURPOSE

At the present time there is a very definite need for boys to understand thoroughly their individual aptitudes for military service, physical work, and athletic performance.

This program with its trained staff, well-equipped research laboratory, and excellent gymnasium, swimming pool, and field facilities, can help each boy understand the key elements of sports fitness and gain an understanding of his potentialities and limitations. The experience the boy gains in this program will help him make the best possible adjustment in the years ahead.

DAILY AFTERNOON SCHEDULE

Group A, 7-8 years; Group B, 9-10; Group C, 11-12; Group D, 13-14

1:30 to 2:00	Group A—Swimming Group B—Track and Field Group C—Conditioning Activities Group D—Gymnastics
2:00 to 2:30	Group A—Gymnastics Group B—Swimming Group C—Track and Field Group D—Conditioning Activities
2:30 to 3:00	Group A—Conditioning Activities Group B—Gymnastics Group C—Swimming Group D—Track and Field
3:00 to 3:15	Break
3:15 to 3:45	Group A—Track and Field Group B—Conditioning Activities Group C—Gymnastics Group D—Swimming
3:45 to 4:15	Endurance Work (Accumulative Mile-athon)
4:15 to 4:30	Free Swim
4:30 to 4:40	Dress

THE PERSONNEL

Dr. King J. McCristal, Dean of the College of Physical Education
Dr. Chester O. Jackson, Head of Dept. of Physical Education for Men
Dr. Thomas K. Cureton, Supervisor and Research Director
Mr. Thomas F. Krizan, Manager
Mr. Michael L. Pollock, Head Instructor, Program Coordinator
Mr. William J. Penny, Swimming Coordinator
Mr. Robert K. Stallman, Swimming
Mr. Richard J. Mulvihill, Track and Field
Mr. Sidney B. Sward, Gymnastics and Posture Training
Mr. Edward L. Sloniger, Conditioning Activities and Games
Mr. Bruce J. Noble, Laboratory Coordinator
Miss Aghdass Farvar, Mr. William Gualtiere, Mr. David E. Cundiff, and **Mr. Bradley L. Rothermel,** Testing, Research Records, and Individual Summaries to Parents
Mrs. Betty Frey, Laboratory Technician and Nurse

II

EVOLUTION OF METHODS FOR DEVELOPING PHYSICAL FITNESS IN BOYS

What Is the Potential of Well-Organized Physical Education?

What improvements in boys could be made with adequate leadership, enough time, and good facilities? Could stamina in youth be developed with the usual sports instruction under favorable conditions? Is a special type of endurance fitness work better? In these questions we have the main hypothesis of this work.

It has long been assumed that the various qualities of physical fitness evolve naturally from participation in games, sports, and physical recreational activities (46). Undoubtedly this does occur to some extent, but at the time of beginning the University of Illinois Experimental Sports-Fitness School in 1950–51 very little proof of this could be found in the research literature of physical education, health education, or child development. It was suspected that too little time, too many unfit leaders, and too few well-trained ones—and even most of these not committed to the training idea—resulted in an inadequate program. The intermittent nature of most of the activities used, too much time spent on rules, demonstration, and "talking" instruction, all caused a large part of the time available to be spent on standing around, listening, and watching.

All too frequently the classes were too large for the teacher to control well. In the schools few classes could ever be observed where the boys were kept busy almost constantly at physical activity of the *endurance* type. Moreover, the typical syllabi examined failed to list any progression in endurance activities, the content being mainly games, stunts and mat work, rhythms, and folk dances—all conducted intermittently without anything lasting in continuous, rhythmic endurance movement for as long as five minutes, whereas endurance is developed only if there are repetitions and sustained activity for 30 minutes or more.

In order to test the effectiveness of the sports instruction program to produce improvement in various traits and qualities of physical fitness, a battery of tests had to be administered at the beginning and at the end of the program. The concept centered upon the idea of a program consisting of

50 per cent of the time spent on sports instruction and play and 50 per cent of the time spent upon testing, direct instruction in the principles of physical fitness, and the practice of endurance work for eight weeks. Follow-up work throughout the year consisted of interviews with the parents and individualized corrective work in small squads of three or four boys working with a leader.

It was the deliberate concept that endurance practices of various kinds could be introduced much earlier than was usual. This would involve routine rhythmical endurance drills lasting five minutes or more; interval training on the indoor and outdoor track, circuit training work alternating running with weight training or body resistance exercises; and also steeplechases over rough ground, uphill and downhill, including climbing, jumping, crawling, and rolling—all on a continuous nonstop basis for one to four miles (32). Such work would always be motivated and led by instructors. A period of such endurance work would be instituted during each day of the sports-fitness school.

In endurance work for stamina training, the great need for motivation looms up as dominant. The limitation among youth is not so much physical inability to do endurance work as it is lack of incentive and cultivation of the trained mind. The instructors must motivate by setting a personal example, by telling fascinating stories of great endurance athletes (i.e., Joie Ray, Paavo Nurmi, Emil Zatopec, Roger Bannister, John Landy, Herbert Elliott, and Peter Snell) and by providing objective methods to evaluate and motivate improvement.

Principal Assumptions of Physical Fitness Work

The principal objective of the experiment, spread over 11 years, was to test some of the major assumptions of physical education work relative to producing physical fitness. Several of these assumptions are as follows:

1. A program of intensive sports and exercises makes beneficial changes in physical fitness quite in addition to "normal growth."
2. Motor ability develops faster and more completely in a situation offering good leadership and instruction, challenging standards for motivation, and sufficient time for practice.
3. Many defects in physique, organic condition, and motor ability respond to fitness and sports training programs, and show measurable improvement in:

   weak feet and legs
   weak arms and shoulders
   weak lateral muscles
   weak muscles of the abdominal region
   weak back muscles
   poor endurance and associated cardiovascular and respiratory conditions
   poor posture

overweight
underweight
poor balance
poor flexibility
poor agility
poor strength
poor power
poor endurance
poor integration of mind and body in physical efforts
poor perseverence to attain a definite goal
poor spirit in the face of an endurance task

4. Improvement in physical fitness is highly associated with improved strength of personality in the face of definite work tasks.

Consideration of Various Methods for Developing Physical Fitness of Boys in the Sports-Fitness School

The main consideration related to methods for developing physical fitness evolved as the *amount of endurance content* in the program, both as to time spent and continuity. It has long been known that endurance is developed by many repetitions of a relatively simple exercise, such as running, swimming, cycling, skating, skiing, etc. The outcomes are general in terms of cardiovascular fitness (fitness of circulation, respiration, blood, heart) but are specific in terms of the particular muscles used. Endurance is developed only in the muscles that are given sufficient training, that is, the specific capillaries and nerve endings in the muscles involved. The endurance content in the Sports-Fitness School was gradually increased over several years; when a practical saturation level was reached, other specific projects were concentrated upon. A review of the 11 years of experimental experience brings forward four main problems other than the amount of time devoted to endurance work. Each of these will be briefly discussed with our experience summated as a principle:

1. *Amount of Leadership per Pupil (Teacher/Pupil Ratio)*

The larger the group the harder it is to reach each and every boy with friendship, personal guidance, and individualized suggestions from the teacher. The large group approach is rather impersonal. It is our full belief that the "man-to-man" approach is the best, one teacher to one pupil. The small squad, as used with teams, is good too, or from two to six boys working with one teacher. The maximum for good work is about 20 boys in one group, but unless they are reasonably homogeneous as to age and ability they will be found to deviate so widely in interests and ability to follow instructions—and to "take" the work—that great inefficiency may result when only one teacher is available. This is especially so in aquatic instruction with both swimmers and nonswimmers on hand, some in shallow water and some in deep water. The most feasible combination is some group work and also some individualized and small squad work.

2. *Number of Exercises or Sports in the Program*

The greater the number of sports and exercises used in a given time available, the smaller is the improvement as an average. Especially is this true in physical fitness items, such as push-ups, sitting tucks, mile run, etc. But it is also true for sports. The attempt to teach well several sports in a day is not as good as concentration upon one, or at the most two sports. There are many, many aspects to any highly organized sport, and time is needed to learn all aspects. Basic instruction may well include several sports; then time should be given for some specialization in a simple chosen sport.

Desirable *skill learning* is quite proportional to the amount of correct repetitions of any movement. In some sports many different skills are involved. Interviews with many champion athletes have revealed that most are specialists and have been specialists all along, for example, John Weismuller (swimming), Bobby Jones (golf), Helen Wills (tennis). From the point of view of organization we see the *club system* and *sport federation system* organized to promote one sport. Beyond a doubt this is more effective for developing any one sport; but physical educators have believed that such specialization should be founded upon a broader base of skills, even at the cost of less intensity in each skill. Over several years it is also undoubtedly true that the attempt to learn many different skills and sports crowds out the emphasis upon endurance.

In our own research experience in the Sports-Fitness School we have sought a way to do some of both, to teach four to six areas during the summer period (swimming, gymnastics and tumbling, track and field, and games), then, after a break, to concentrate on specific corrective and developmental projects to develop particular types of fitness individually or in small groups during the rest of the year. The best improvements have undoubtedly come from these concentrated projects as carried out in corrective aspects, or in rope-skipping (129), cycling (113), skating (106, 123), etc. We have also encouraged specialization in a single sport during each season.

3. *Types of Activities Included in the Program*

The typical elementary school program has usually emphasized games, skills, and rhythms. The new trends have led to physical fitness work using activities which require more resistance (for strength), more continuous repetitions (for endurance), and activities which can keep all boys active practically all the time. Some of these activities are:

Fitness test batteries (like the 18-Item Test, 1 hour)

Continuous, progressive, muscular endurance exercises in series, i.e., sometimes arranged as "circuit training" with weights or endurance exercises at a series of stations

Obstacle courses (run slow, medium, and fast speeds)

Steeplechases (or paperchases), 30 minutes or more, or "bush-walking"
Interval training (30 minutes or more) in running, rowing, cycling, swimming, etc.
Medicine balls or pulley weights (30 minutes or more)
Rowing machines or treadmills (worked slow, medium, and fast)
Road running (30 minutes or more), or alternate jog-walk, etc.
Hikes (2 hours or more) with 2 minutes rest after each mile
Cycling trips, or canoeing trips (several hours or days)

Here we have the contrast between sports instruction and definitely conceived fitness activities, the main concept being that enough big-muscle activity on a more continuous basis will develop more stamina and make better use of the time available. Such activities will force more time to be spent, either in the formal program, or at home on weekends, because no regular school has enough time available within the typical crowded school day. Endurance activity should be practiced during after-school hours and on weekends.

4. *Progressive Dosage* (*low to middle to high gear*)

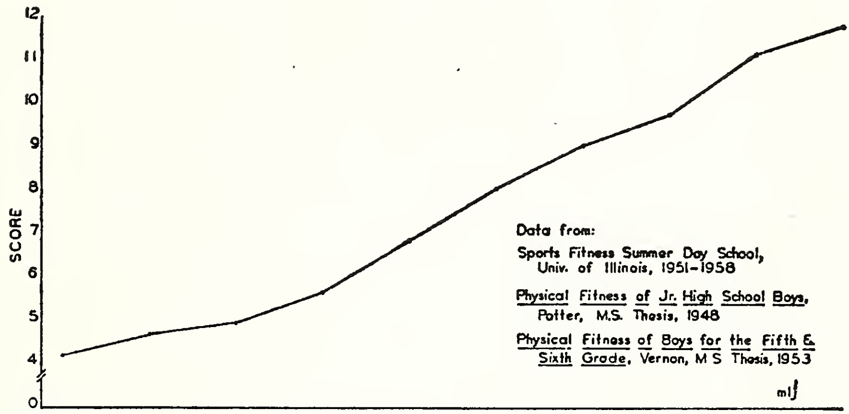
The activities should be paced to permit continuous activity. One strenuous 400-meter (440-yard) run may be all a boy can take. This will involve from 1 to 2 minutes of activity. But the run should be followed by walking. A slower run may permit several such alternate run-walks. It has been proved that cardiovascular fitness is developed by interval training, cross-country running, canoe trips, long cycling rides, long hikes, and by gradually working at a faster and faster pace. If one plays a game (perhaps softball) just the same way each time, and usually at submaximal effort, endurance does not improve. This is the fallacy in using games, rhythms, or gym stunts to develop fitness. Exercise should begin gradually 15 to 20 minutes to warm up; then there should be peaks or spurts of activity; then some long drawn-out endurance work. This should usually occur all in a single period.

In recent years the "interval training" idea has been adopted in all endurance sports, that is, the idea of many work periods alternated with rest periods, with the work periods gradually faster and even longer as the weeks of training proceed, the dosage involving more and more time and the rest intervals gradually shortened. Thus, there is systematic *progression* of dosage. The physiologists call this "overload," and it may be either against resistance or as an endurance (circulatory-respiratory) overload for a longer time. The former develops strength and the latter develops cardiovascular condition. But set 30-minute class periods do not accommodate well to this system, which takes more and more time as more and more endurance is sought.

III

AGE AND PHYSICAL FITNESS IN BOYS

When we examine the various graphs plotted to show the variation in physical fitness with different ages, we note that there is a general rise from 6 to 14 years in practically all of the tests and measurements examined (Figures 2 to 43). These charts have been classified into three groups: (a) motor fitness, (b) physique, (c) cardiovascular condition. In general the physical ability improvements with age are reflected best in the graph of the 18-Item Motor Fitness Test (Figure 2). There is a steady improve-

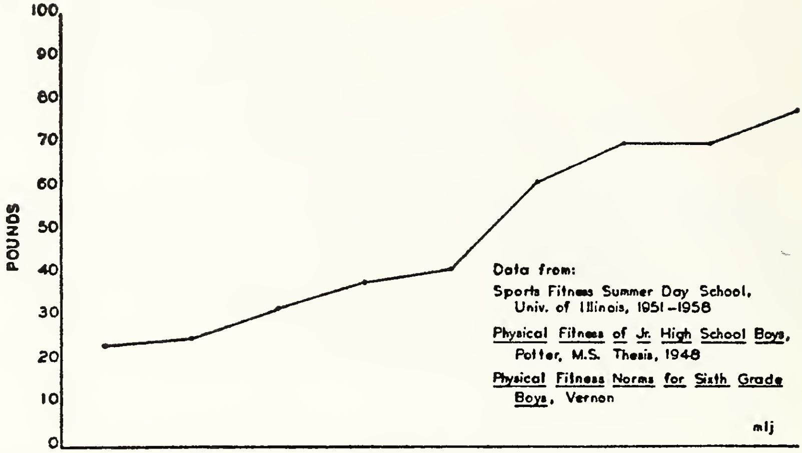


Age	6	7	8	9	10	11	12	13	14	15
Mean	4.20	4.73	4.99	5.62	6.86	8.02	9.03	9.79	11.13	11.79
Number	10	52	79	77	108	108	146	115	137	29
σ	2.89	2.50	2.51	2.97	2.80	2.81	3.54	3.01	3.02	2.76

Figure 2—18-Item Motor Fitness Test vs. age (boys).

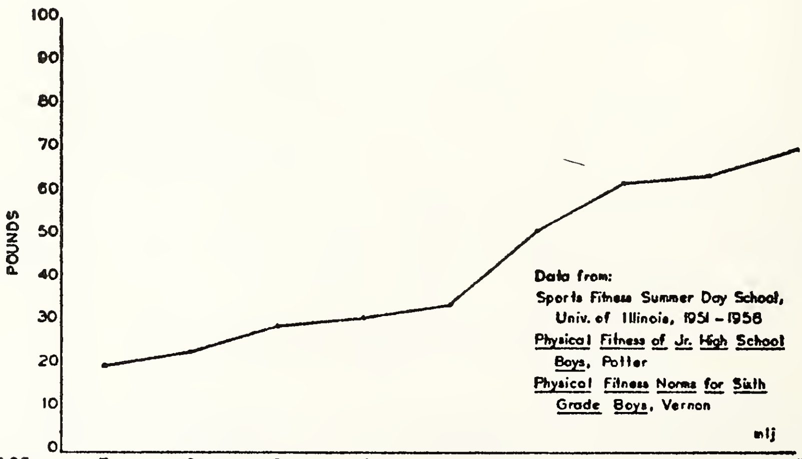
ment in ability from 6 to 14 years of age. It is to be expected that as experience increases there will be increased mastery of motor stunts. The slope of the curves is gradually upward without any plateau, break, or unusual deviation at any year of age.

The strength graphs (Figures 3 to 8) follow a similar trend, but there is clearly some acceleration in strength from 11 to 12 years of age upward.



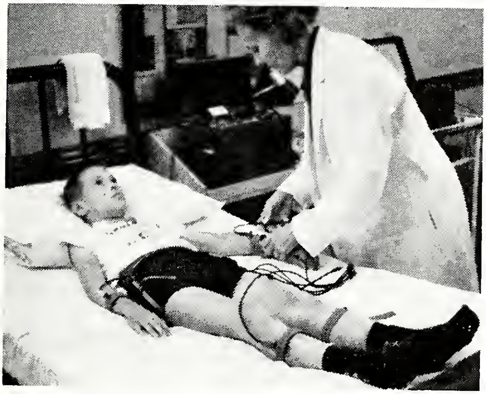
AGE	7	8	9	10	11	12	13	14	15
MEAN	22.9	25.2	32.5	37.6	41.2	61.3	70.4	69.8	77.7
NUMBER	53	79	77	105	105	109	71	89	19
σ	8.4	8.5	8.4	8.9	10.6	25.0	18.8	19.7	17.3

FIGURE 3—Dynamometer strength—right grip vs. age (boys).

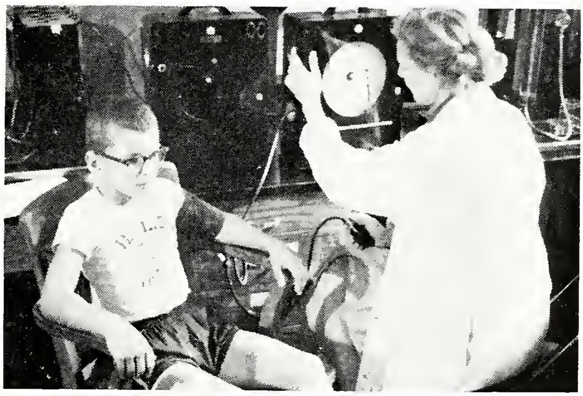


AGE	7	8	9	10	11	12	13	14	15
MEAN	19.9	22.6	28.6	31.0	33.6	51.5	61.7	63.6	69.7
NUMBER	53	78	77	105	105	109	70	89	19
σ	7.5	5.4	9.5	10.2	10.5	20.9	14.9	20.0	16.6

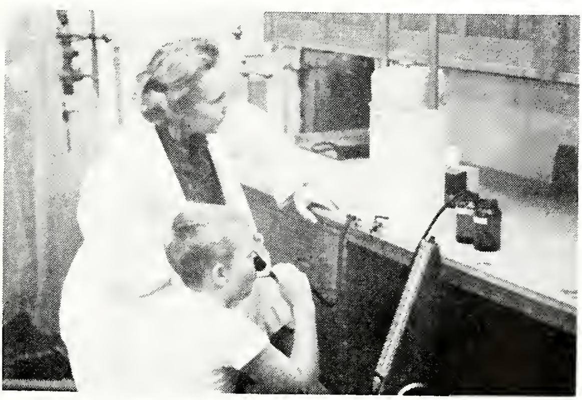
FIGURE 4—Dynamometer strength—left grip vs. age (boys).



(a) Attaching electrodes prior to recording electrocardiogram.



(b) Recording brachial pulse wave on the heartometer.



(c) Recording maximal breathing capacity (vital capacity).

Plate I—Physical Fitness Laboratory: testing procedures.

(a) Recording footprint and measuring scaphoid deviation.

(b) Assessment of leg power in the vertical jump.

(c) The appraisal of physique: here, the recording of chest depth.

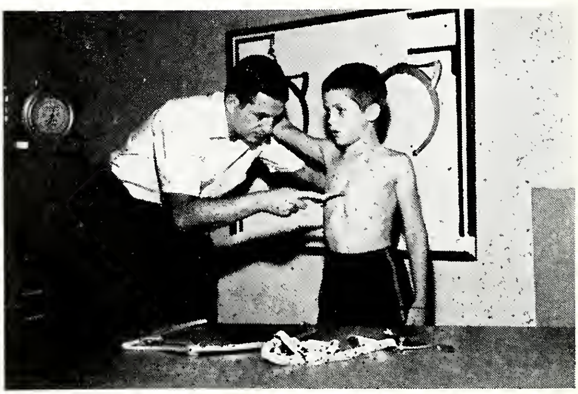
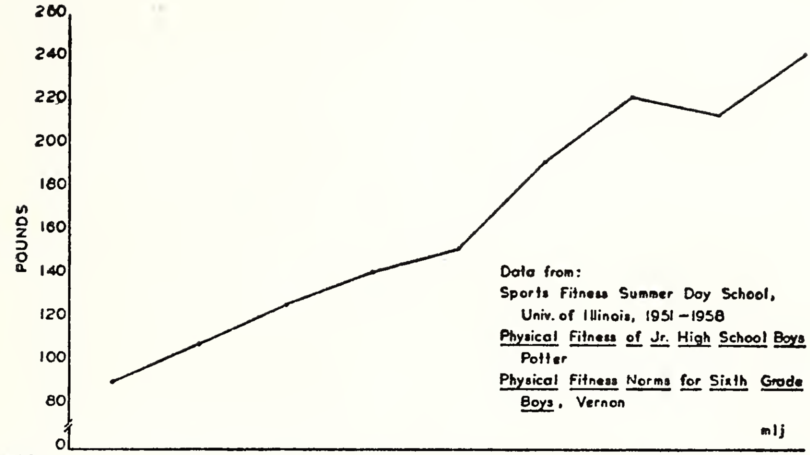
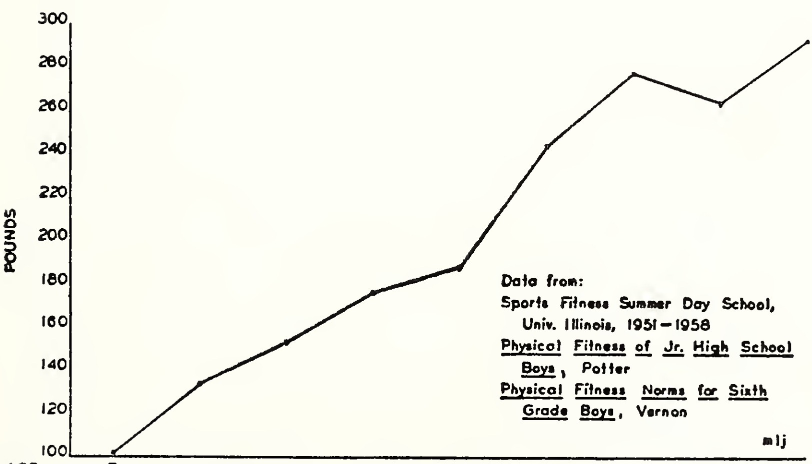


Plate II—Physical Fitness Laboratory: testing procedures.



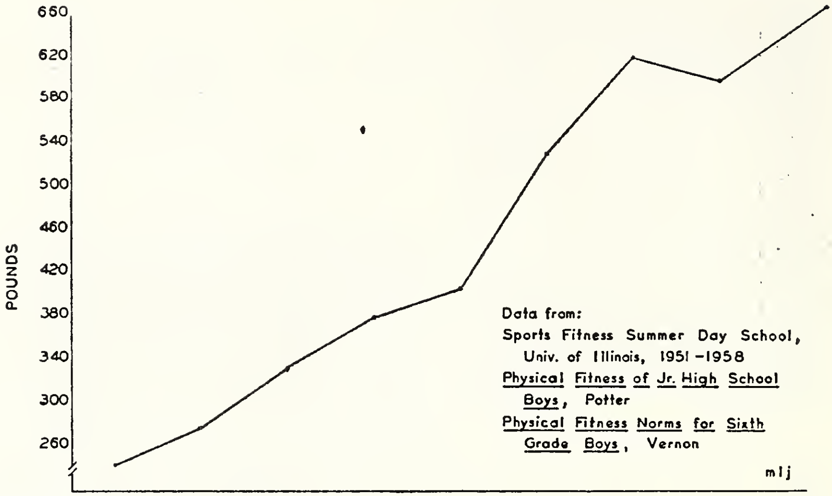
AGE	7	8	9	10	11	12	13	14	15
MEAN	91.23	108.33	125.78	141.38	151.29	192.39	221.41	211.51	241.83
NUMBER	53	78	77	105	105	109	71	89	19
σ	24.4	32.0	33.2	31.1	32.2	81.8	60.4	63.0	61.5

FIGURE 5—Dynamometer strength—back lift vs. age (boys).



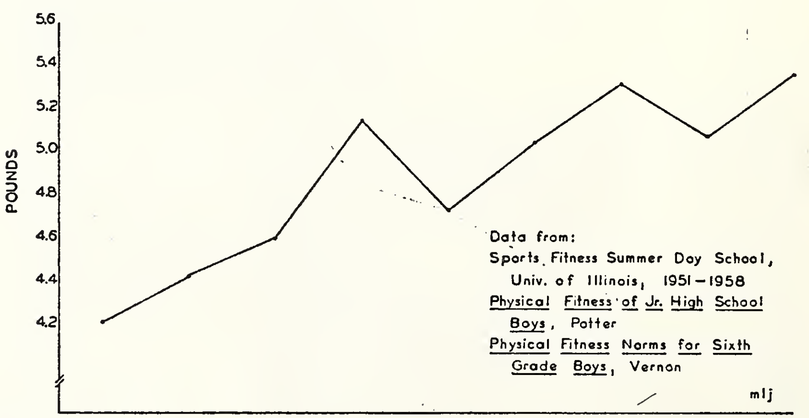
AGE	7	8	9	10	11	12	13	14	15
MEAN	103.40	133.59	153.12	177.43	187.50	244.22	277.61	264.15	293.12
NUMBER	53	78	77	105	105	109	71	89	19
σ	35.6	46.0	48.6	46.2	45.8	81.8	86.2	99.4	118.8

FIGURE 6—Dynamometer strength—legs extension vs. age (boys).



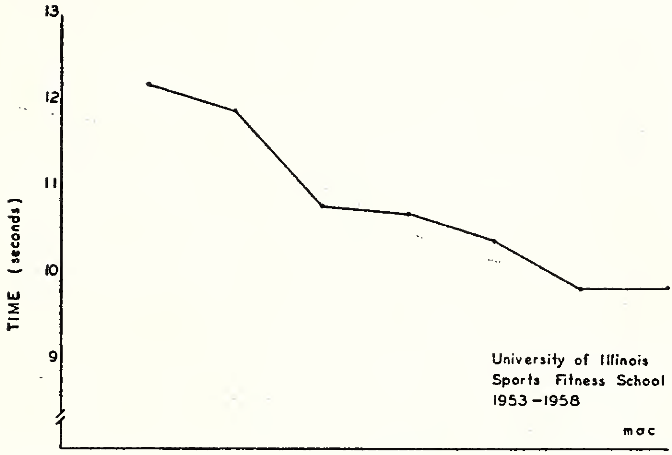
AGE	7	8	9	10	11	12	13	14	15
MEAN	242.83	278.46	333.60	380.60	405.95	533.26	620.77	598.58	667.09
NUMBER	53	78	77	105	105	109	71	89	19
σ	59.1	76.2	81.9	82.4	93.2	176.3	155.8	186.6	191.4

Figure 7—Dynamometer strength—sum of four items vs. age (boys).



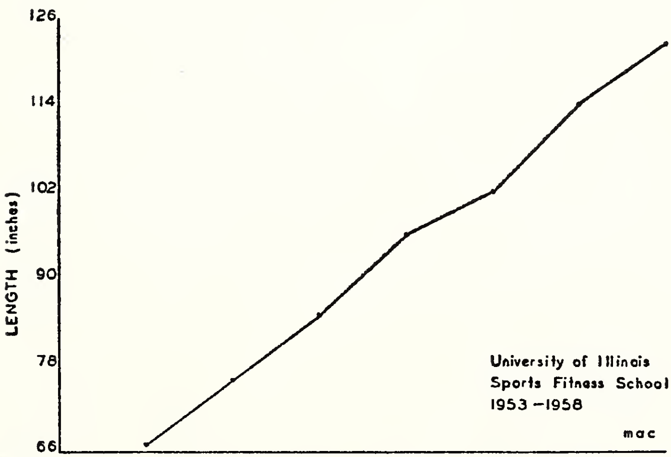
AGE	7	8	9	10	11	12	13	14	15
MEAN	4.22	4.43	4.61	5.15	4.74	5.05	5.32	5.08	5.37
NUMBER	52	78	76	90	92	103	71	89	19
σ	1.0	1.1	1.1	1.3	1.2	1.5	1.1	1.2	1.8

Figure 8—Dynamometer strength—per pound of body weight (boys).



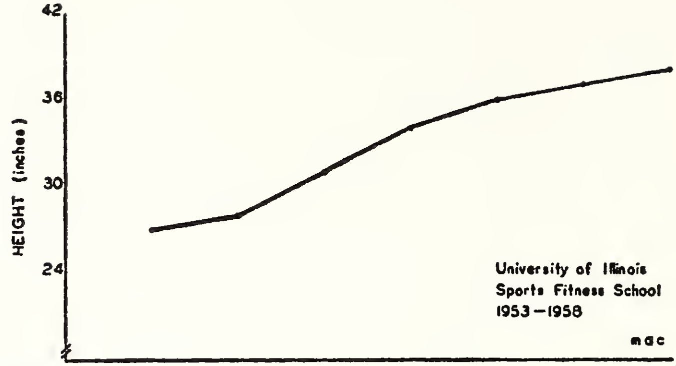
AGE	7	8	9	10	11	12	13
MEAN	12.2	11.9	10.8	10.7	10.4	9.85	9.85
NUMBER	31	55	50	42	46	15	10
σ	1.19	1.87	1.08	.62	.95	1.32	.49

FIGURE 9—Sixty-yard dash (boys).



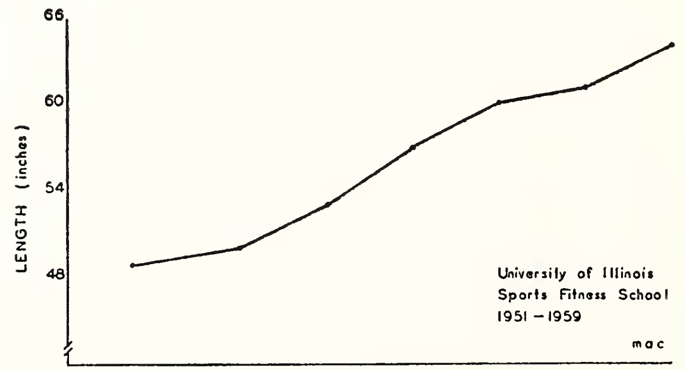
AGE	7	8	9	10	11	12	13
MEAN	68	76	85	96	102	114	123
NUMBER	34	45	58	42	39	12	8
σ	15.8	19.4	14.7	15.2	20.3	18.1	15.5

FIGURE 10—Running broad jump (boys).



AGE	7	8	9	10	11	12	13
MEAN	27	28	31	34	36	37	38
NUMBER	30	62	57	44	44	12	9
σ	4.05	3.95	3.61	3.25	5.41	4.50	6.12

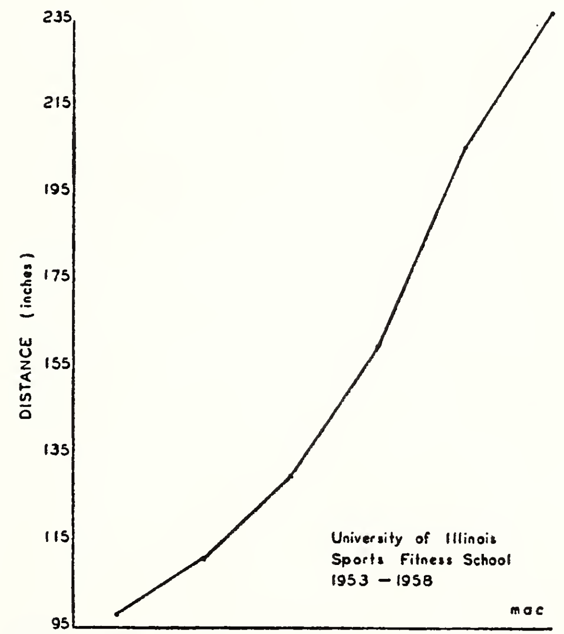
Figure 11—Running high jump (boys).



AGE	7	8	9	10	11	12	13
MEAN	49	50	53	57	60	61	64
NUMBER	61	75	59	54	39	23	14
σ	6.72	7.18	3.71	7.76	6.80	9.78	5.55

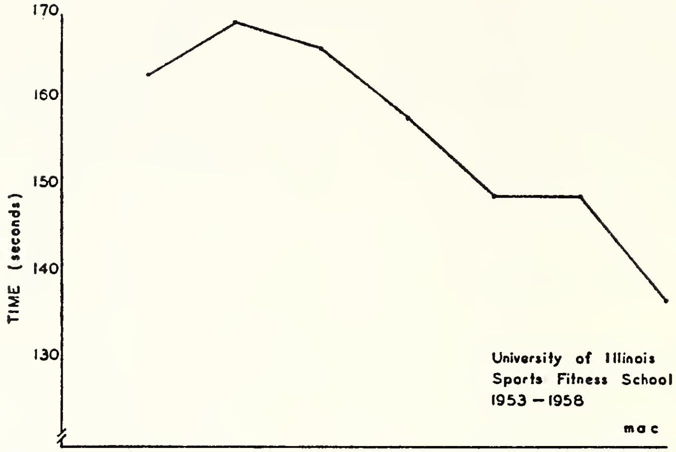
Figure 12—Standing broad jump (boys).

This seems to begin just at the onset of the prepubertal growth and continues will into postadolescence. Other studies with young men and adults show that this curve continues upward until about 25 years of age and then reverses into a downward trend, which declines steadily from 26 to 60 years of age. All track and field events dominated by strength and power follow this same trend (see Figures 9 through 14 for 60-yard dash, running broad jump, running high jump, standing broad jump, shot-put, and 600-yard run). Upper-body dynamic strength (chins and dips, Figures 15 and 16) does not begin to improve until 11 years of age, but push-ups (Figure 17) improve very gradually from 8 to 13 years.



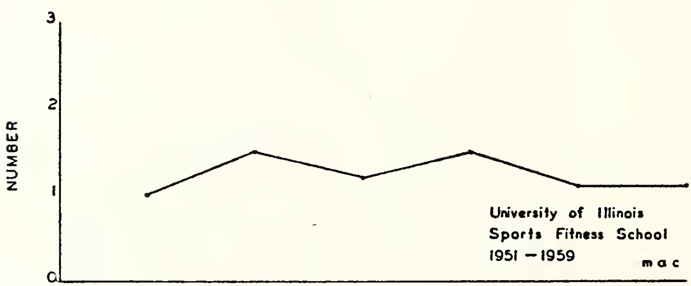
AGE	7	8	9	10	11	12
MEAN	98	111	130	160	206	237
NUMBER	12	32	29	20	9	6
σ	12.4	23.6	22.9	25.4	17.3	37.6

FIGURE 13—Shot-put (8 pounds) (boys).



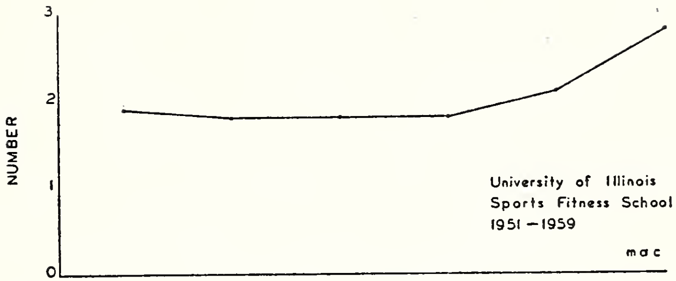
AGE	7	8	9	10	11	12	13
MEAN	163	169	166	158	149	149	137
NUMBER	17	43	41	29	31	16	10
σ	17.80	24.89	23.85	21.37	22.97	22.69	9.57

FIGURE 14—Six hundred - yard run (boys).



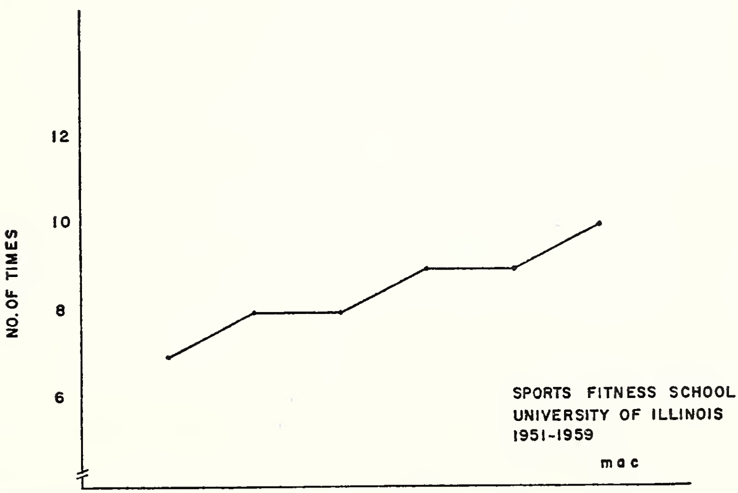
AGE	7	8	9	10	11	12
MEAN	1.0	1.5	1.2	1.5	1.1	1.1
NUMBER	24	55	53	53	11	12
σ	1.18	.39	1.65	.43	1.29	1.34

FIGURE 15—Chins (boys).



AGE	7	8	9	10	11	12
MEAN	1.9	1.8	1.8	1.8	2.1	2.8
NUMBER	26	57	54	53	12	12
	1.90	1.91	2.13	2.37	2.54	2.75

FIGURE 16—Dips (boys).



AGE (YRS.)	8	9	10	11	12	13
MEAN (TIMES)	7	8	8	9	9	10
NUMBER	71	69	80	48	33	16
σ	4.3	5.7	5.6	5.1	6.1	6.6

FIGURE 17—Floor push-ups vs. age (boys).

Some Hints Related to Developing Endurance

Two or three weeks as a minimum are needed for untrained boys to adjust to a fairly vigorous physical program. Some never adjust fully even in eight weeks. At first, new exercises are apt to induce some muscular soreness and indisposition to go on with the exercise. This situation enforces a gradual approach or, at least initially, the introduction of recuperation (play) days between bouts of hard endurance work. It is probably better at the beginning of the course to introduce a good amount of low-gear work and to alternate instruction, endurance, and play; a gradual progression in intensity and duration should be in mind.

In a single day, any very hard exercise should be of short duration, followed by a definite effort to breathe deeply while walking. In continuous exercises a hard exercise may be followed by an easy exercise along with emphasis on breathing. As a rule, youngsters do not know how to alternate exercises in this manner or how to breathe deeply. Another principle is to work one set of muscles and then change to another set, thus resting the first set. This requires an experienced instructor who knows how to lead these sequences.

Endurance training involves the readiness and adjustment of the mind to the work, as well as forcing the body to make physiological adjustments. It is now believed that the usual concept of "standards" in endurance is very low indeed in the pupil's mind. The period over the past 15 years has certainly been one of low ideals in relation to standards of human stamina. Our best endurance athletes in running, skating, skiing, cycling, and all such kindred endurance sports, have been badly outclassed in the Olympic Games. Endurance development has been hindered by too much rich, overprocessed, packaged food. But the 1964 Olympics reflected a reversed trend as shown in the outstanding performances in swimming and track.

There is no substitute for time; there is no real short cut. The improvement in stamina is quite proportional to the time spent.

Test items for the arms and shoulders show a notable exception in that chinning and dipping (Figures 15, 16), requiring the whole body weight to be pulled upward or pushed upward by the arm and shoulder muscles, virtually do not improve from 7 to 12 years of age for chinning and from 7 to 10 years of age for dipping. This is in sharp contrast to the vertical jump (Figure 18), which improves steadily from 7 to 12 years of age, with some slight acceleration after 11 years of age. Poor shoulder strength reflects an inadequate overhead and upper body program according to Hutinger (76). He found that 10 minutes per day, 5 days per week, continued for 3 months, of hard resistance exercise resulted in improving 8-, 9-, and 10-year-old boys significantly in push-ups, pull-ups, and in pulling and pushing strengths as compared with a control sample of boys. In our work

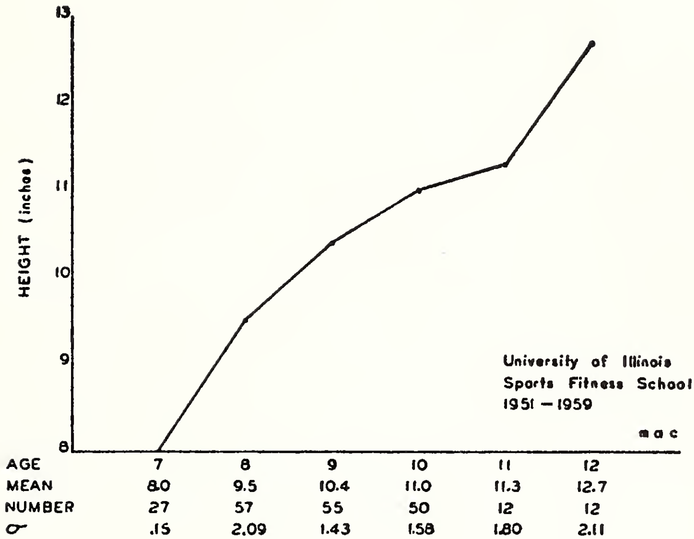


FIGURE 18—Vertical jump vs. age (boys).

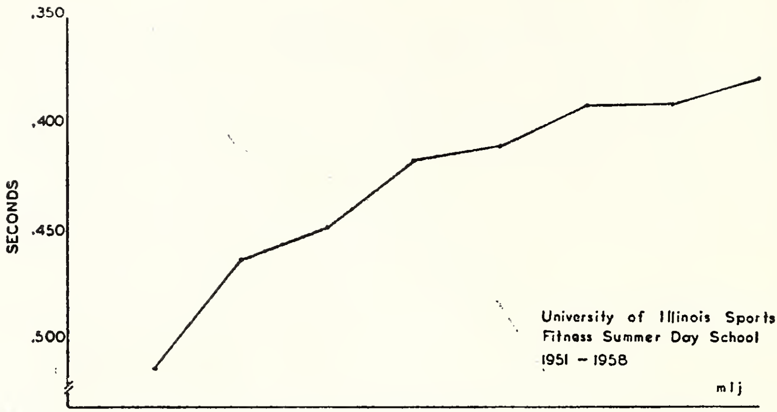
we improved a young girl during the span of 13 to 16 years from 3 to 60 push-ups done with the back held straight like a boy. In addition to push-ups we used pulley weights and medicine balls for the developmental work.

The visual and auditory (Figures 19 and 20) reaction items respond in a similar manner and are presumably related to the intensity of muscular force which can be instantaneously commanded in springing the whole body upward. The combined signal gives a similar curve (Figure 21). The agility run average improves steadily from 25.27 seconds at 6 years of age to 18.98 seconds at 15 years of age (not shown).

Gains in physique parallel those in strength very closely with height (Figure 22), improving steadily in increments from 48 inches at 6 years of age to 65.85 at 15 years of age. Weight (Figure 23) improves in a regular way from 52.08 pounds at 6 years of age to 129.93 pounds at 15 years of age.

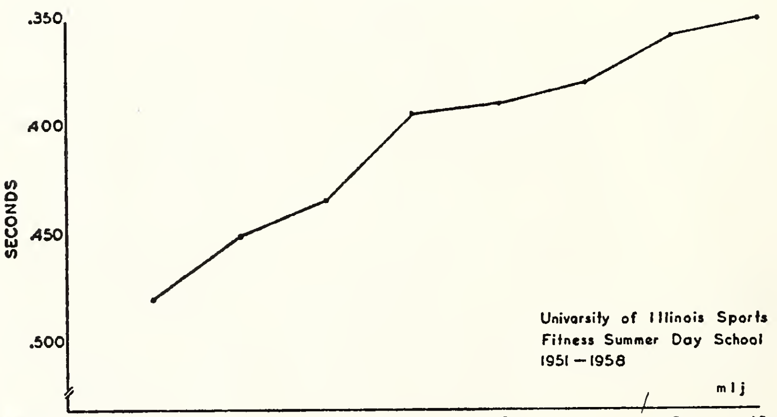
Our curves for the various physique measurements closely parallel those reported by Schwartz, Britten, and Thompson (139) in 1928, except that our sample is slightly heavier and a bit taller.

The reciprocal of the ponderal index increases slightly from 13.00 to 13.08 from 7 to 8 years of age, remains almost constant to 9 years of age, then wavers up and down between 13.06 and 13.10 to 13 years of age (Figure 24).



AGE	6	7	8	9	10	11	12	13
MEAN	.5123	.4625	.4471	.4173	.4096	.3912	.3908	.3792
NUMBER	10	51	76	71	47	33	19	11
σ	.0978	.0870	.0852	.0660	.0792	.0885	.0539	.0805

Figure 19—Visual reaction time vs. age (boys).



AGE	6	7	8	9	10	11	12	13
MEAN	.4793	.4500	.4326	.3931	.3892	.3791	.3583	.3501
NUMBER	10	51	76	71	47	33	19	11
σ	.0782	.0882	.0810	.0611	.0642	.0823	.0575	.0884

Figure 20—Auditory reaction time vs. age (boys).

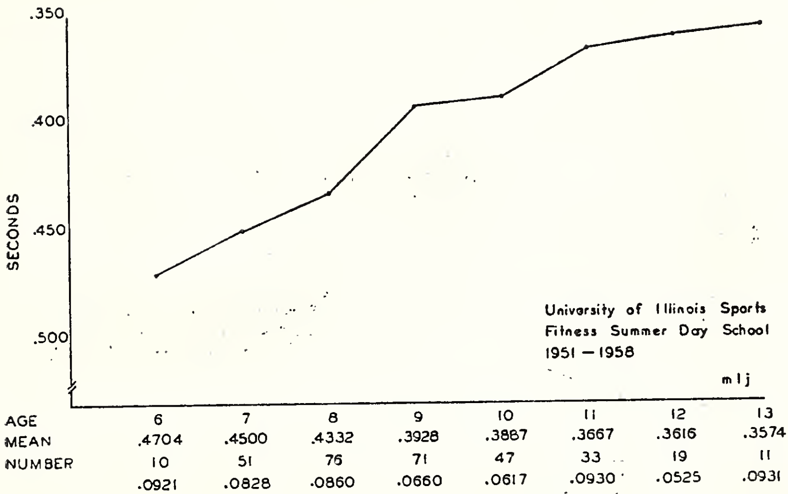


FIGURE 21—Combined (visual + auditory) reaction time vs. age (boys).

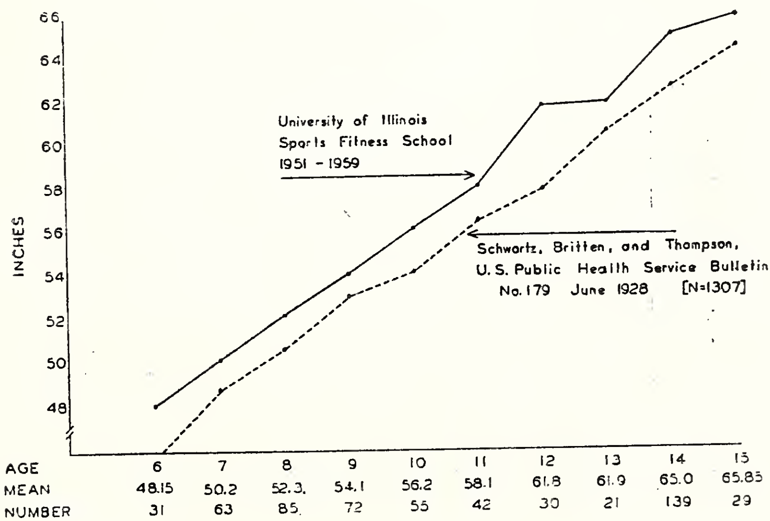
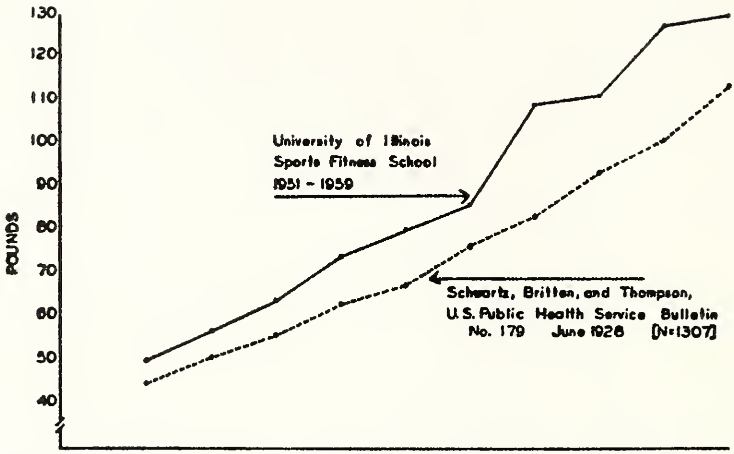
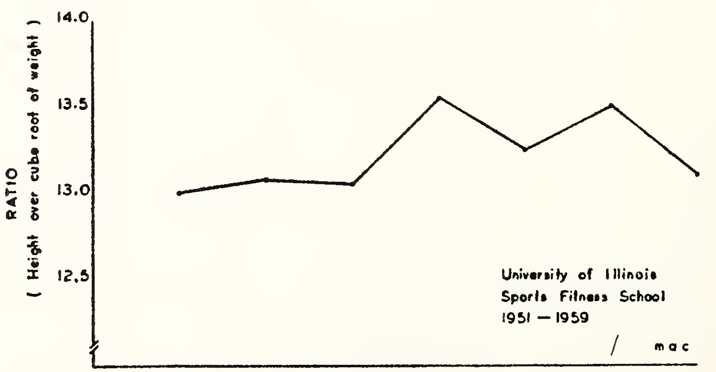


FIGURE 22—Height vs. age (boys).



AGE	6	7	8	9	10	11	12	13	14	15
MEAN	52.08	57.0	64.0	74.0	80.0	86.0	109.0	111.0	127.24	129.93
NUMBER	31	62	85	75	55	42	30	21	139	29

FIGURE 23—Weight vs. age (boys).



AGE	7	8	9	10	11	12	13
MEAN	13.00	13.08	13.06	13.54	13.23	13.50	13.10
NUMBER	63	83	63	55	46	30	20
σ	.3827	.6004	.6226	.4261	.7488	.6256	.7063

FIGURE 24—Reciprocal of the ponderal index ratio vs. age (boys).

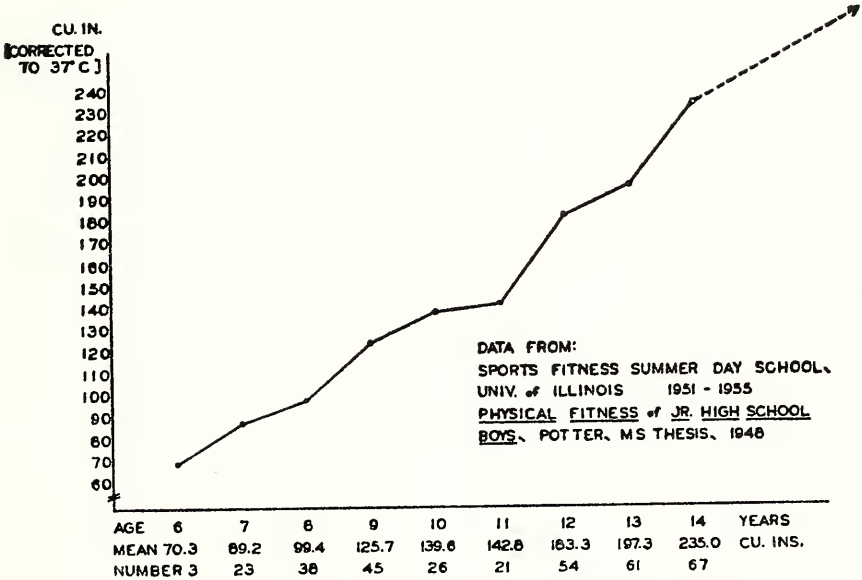


Figure 25—Vital capacity (boys).

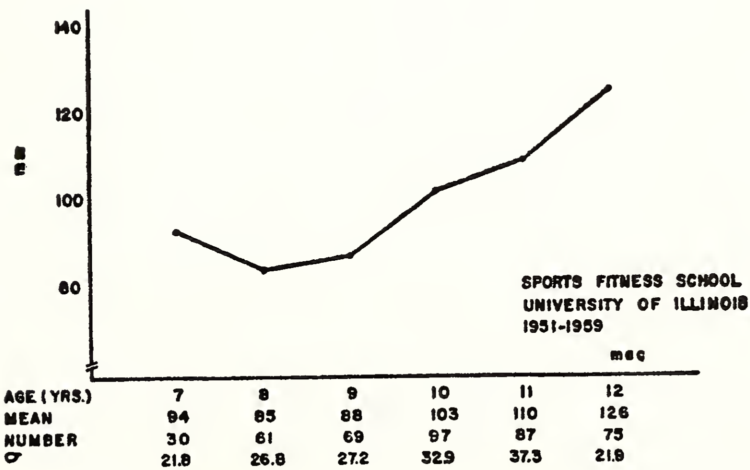


Figure 26—Sum of six fat folds vs. age (boys).

Vital capacity also makes a steady improvement, paralleling physical growth (Figure 25). Fat also increases from 94 mm. at 7 years of age (double fold pinch-up) to 153 mm. at 13 years of age (Figure 26).

The Flack breath-holding test (Figure 27) is much the same, except that the dip is at 11 years of age rather than 12. Chest expansion (Figure 28) improves gradually with age. Maximum expiratory force (Figure 29) ranges from 59.3 mm. Hg at 6 years of age to 94.8 mm. Hg at 12 years of age, then from 12 to 13 there is a dip in the curve, after which there is a steady climb. Chest girth minus abdominal girth (Figure 30) does not improve until 11 years of age.

Tests of cardiovascular condition are much more irregular, but there is steady improvement in the height of the highest precordial *T* wave (Figure 31), from 7.30 mm. at 6 years of age to 9.90 mm. at 12 years of age; at 13 there is a dip in the curve seemingly just at the point where physical maturing is at its peak, after which the curve rises gradually again to 14 years of age.

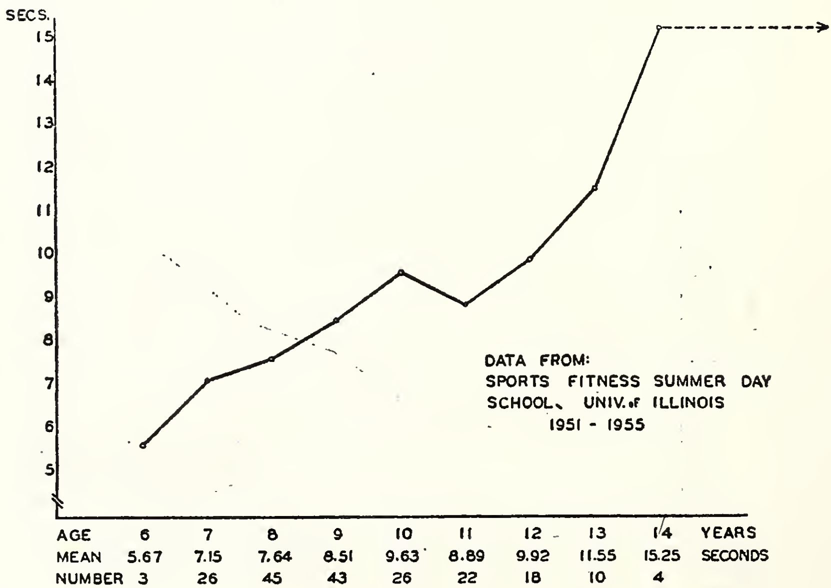
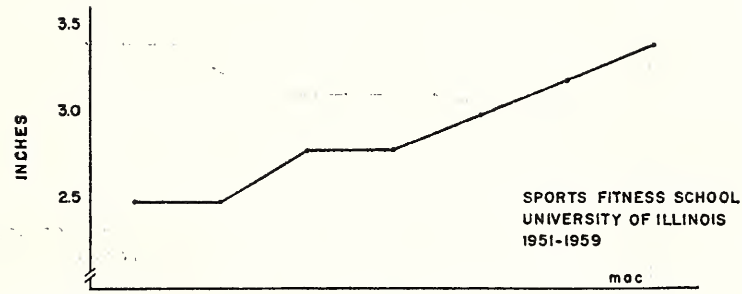
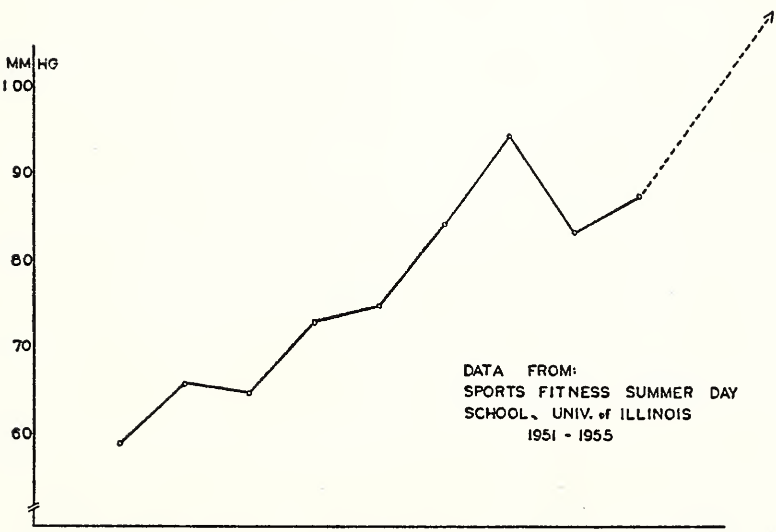


FIGURE 27—Flack breath-holding test (after 60-sec. step-up, 30/min.) vs. age (boys).



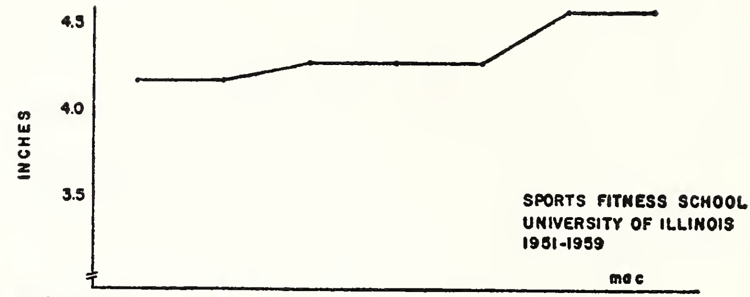
AGE (YRS.)	7	8	9	10	11	12	13
MEAN	2.5	2.5	2.8	2.8	3.0	3.2	3.4
NUMBER	55	90	86	87	70	43	22
σ	0.62	0.59	0.65	0.55	0.76	0.75	1.16

Figure 28—Chest expansion vs. age (boys).



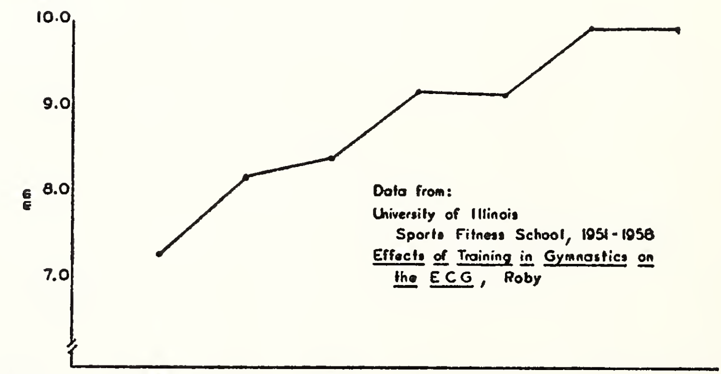
AGE	6	7	8	9	10	11	12	13	14 YEARS
MEAN	59.3	66.3	65.1	73.2	75.3	84.6	94.8	83.7	87.8 MM HG
NUMBER	3	27	46	45	26	22	18	10	4

Figure 29—Maximum expiratory blow vs. age (boys).



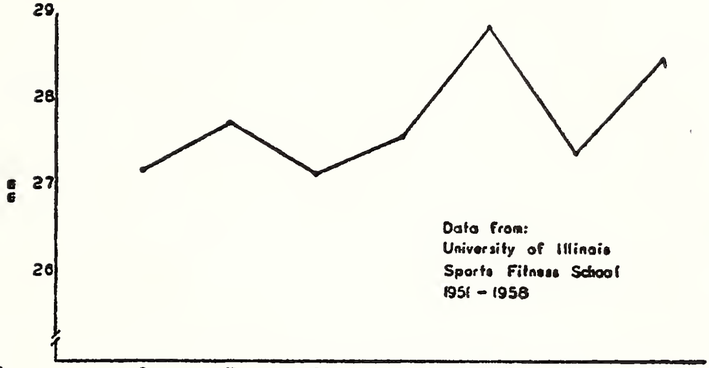
AGE (YRS.)	7	8	9	10	11	12	13
MEAN	4.2	4.2	4.3	4.3	4.3	4.6	4.6
NUMBER	55	90	86	87	70	43	22
σ	1.71	1.01	1.51	1.56	1.83	1.48	2.08

FIGURE 30—Expanded chest girth minus abdominal girth vs. age (boys).



AGE	6	7	8	9	10	11	12
MEAN	7.30	8.20	8.42	9.19	9.15	9.92	9.92
NUMBER	11	48	78	70	53	36	20
σ	2.48	3.14	2.90	3.20	3.29	3.60	4.36

FIGURE 31—*T* wave of the ECG (boys).



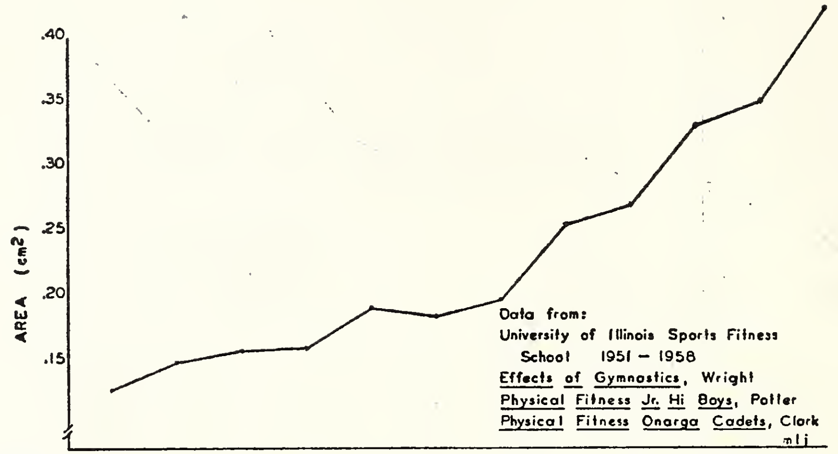
AGE	6	7	8	9	10	11	12
MEAN	27.20	27.74	27.14	27.59	28.84	27.40	28.47
NUMBER	9	46	76	68	51	35	20
σ	8.10	8.40	7.51	7.97	6.54	7.59	8.14

FIGURE 32—*R* wave of the ECG (boys).

The highest precordial *R*-wave curve (Figure 32) begins at 27.20 mm. at 6 years of age and fluctuates between this amplitude and 28.49 mm. at 12 years of age, after which there is a sharp dip at 13 years, similar to the *T* wave described above. Transient fatigue lowers both the *T* and *R* waves. The age of 13, just as sexual maturity is developing in most boys, is associated with this fatigue phenomenon.

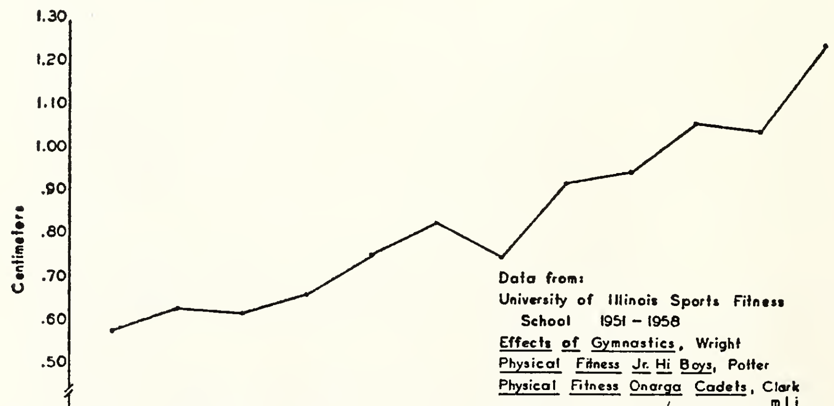
Statistically, the various electrocardiograph measurements, such as the *Q* wave, *S* wave, *P* wave, *QRS* complex, and *P-QR* interval, are insignificantly related to age. They are much more indicative of fitness. Elongations of the *P-QR* interval and the time of the *QRS* complex are usually indicative of fatigue, as are depressions of the *R* and *T* waves or enlargements of the *Q*, *S*, and *P* waves.

The heartograph (brachial pulse wave) area rises from 0.127 at 6 years of age to 0.197 at 12 years of age, after which it rises more sharply to 0.422 sq. cm. at 17 years of age (Figure 33). The systolic amplitude of the brachial pulse wave (Figure 34) looks very similar to the area curve and begins at 0.584 cm. at 6 years of age and rises to 0.755 cm. at 12 years, after which it rises more sharply to 1.245 cm. at 17. The obliquity angle (Figure 35) steadily declines from 30.48° at 6 years to 23.90° at 11, then reverses to 26.59° at 13, and then to 20.88° at 17 years of age. There are steady but smaller increases in lying systolic blood pressure (Figure 36) from 96.6 mm. Hg at 7 years of age to 104.2 mm. at 12, and 114 at 15 years of age. The curve of standing systolic blood pressure is much the same.



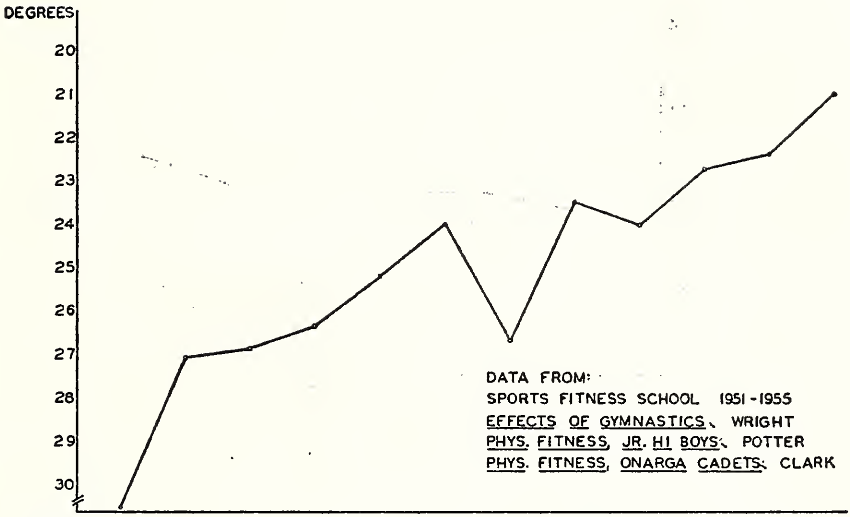
AGE	6	7	8	9	10	11	12	13	14	15	16	17
MEAN	.127	.149	.157	.161	.192	.185	.198	.255	.271	.333	.350	.422
NUMBER	7	54	80	72	58	48	60	66	68	32	32	20
σ	.031	.049	.085	.084	.070	.072	.077	.097	.105	.143	.112	.128

FIGURE 33—Area of brachial pulse wave vs. age (boys).



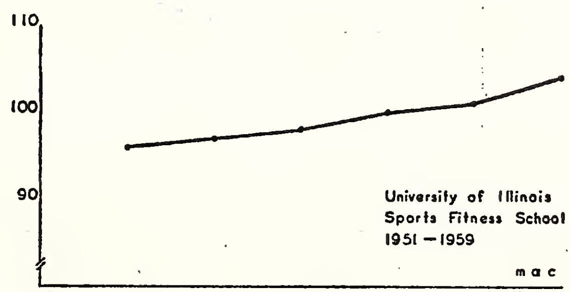
AGE	6	7	8	9	10	11	12	13	14	15	16	17
MEAN	.584	.637	.626	.668	.760	.823	.755	.927	.952	1.066	1.047	1.245
NUMBER	14	54	81	72	58	47	61	66	68	32	32	20
	.173	.175	.214	.188	.233	.231	.280	.307	.289	.306	.257	.235

FIGURE 34—Systolic amplitude of brachial pulse wave vs. age (boys).



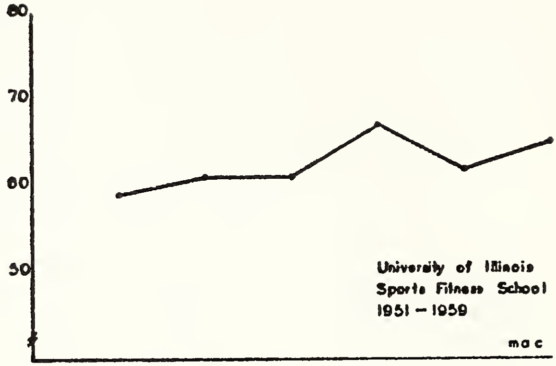
AGE [YRS]	6	7	8	9	10	11	12	13	14	15	16	17
MEAN [DEGREES]	30.48	26.98	26.76	26.23	25.11	23.90	26.59	23.44	23.87	22.62	22.23	20.88
NUMBER	7	31	48	48	33	36	53	61	68	32	32	20

FIGURE 35—Obliquity angle—heartograph (boys).



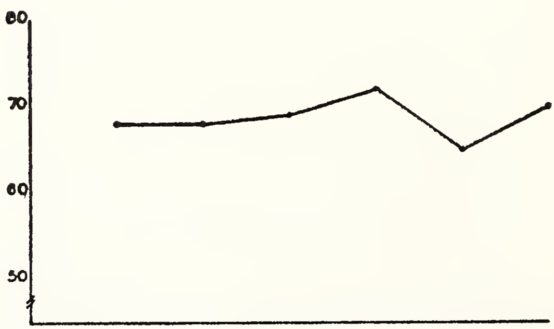
AGE	7	8	9	10	11	12
MEAN	96	97	98	100	101	104
NUMBER	26	30	37	73	42	44
σ	7.7	6.9	7.6	7.5	4.6	5.9

FIGURE 36—Lying systolic blood pressure vs. age (boys).



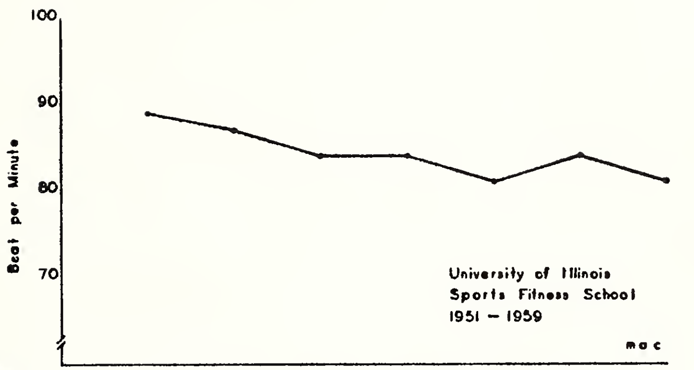
AGE	7	8	9	10	11	12
MEAN	59	61	61	67	62	65
NUMBER	25	28	30	67	39	39
σ	17.7	16.9	13.6	8.9	12.7	11.8

Figure 37—Lying diastolic blood pressure vs. age (boys).



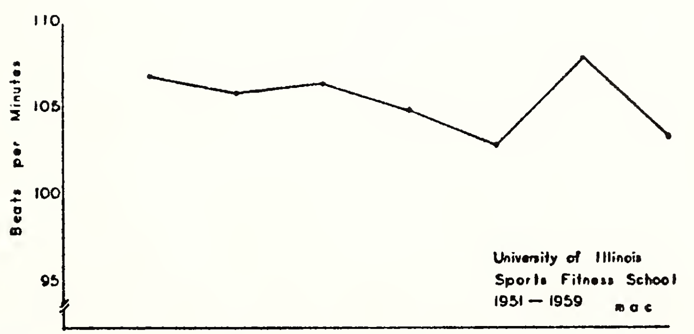
AGE	7	8	9	10	11	12
MEAN	68	68	69	72	65	70
NUMBER	23	25	29	70	38	40
σ	16.4	18.9	16.0	8.8	8.9	15.9

Figure 38—Standing diastolic blood pressure vs. age (boys).



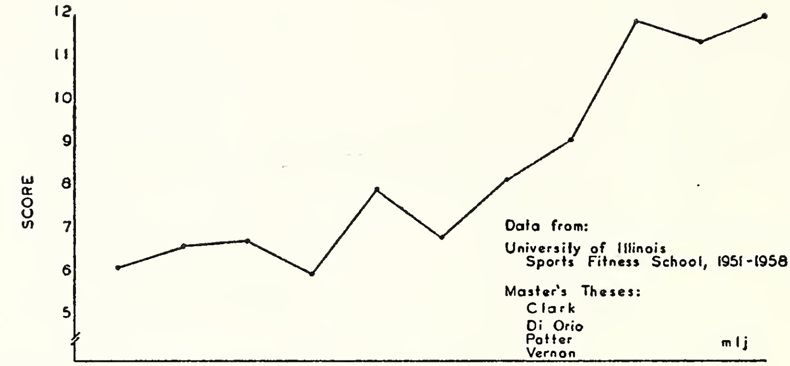
AGE	7	8	9	10	11	12	13
MEAN	89	87	84	84	81	84	81
NUMBER	52	69	66	53	35	22	15
σ	10.385	9.315	9.045	10.350	10.310	8.940	13.366

Figure 39—Lying pulse rate related to age (boys).



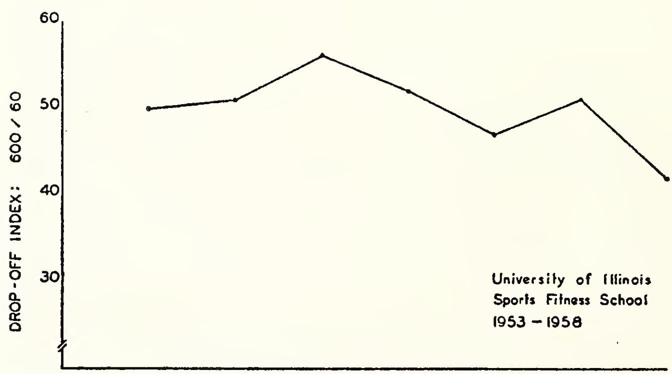
AGE	7	8	9	10	11	12	13
MEAN	107	106	106.5	105	103	108	103.5
NUMBER	52	67	62	47	35	26	15
σ	13.720	11.370	10.350	10.950	15.140	11.430	15.002

Figure 40—Standing pulse rate related to age (boys).



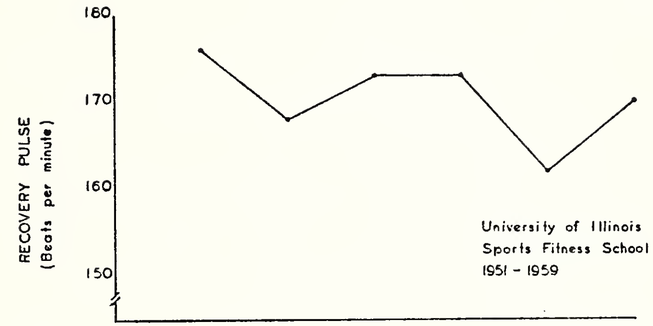
AGE	7	8	9	10	11	12	13	14	15	16	17
MEAN	6.14	6.67	6.77	6.00	7.96	6.83	8.17	9.09	11.82	11.37	11.90
NUMBER	43	60	82	157	162	116	63	70	33	30	20
σ	4.01	3.04	3.45	2.84	3.05	3.91	4.73	4.29	4.15	4.24	3.22

FIGURE 41—Schneider index vs. age (boys).



AGE	7	8	9	10	11	12	13
MEAN	50	51	56	52	47	51	42
NUMBER	21	43	40	28	25	9	9
σ	16.0	19.4	18.1	14.4	18.0	16.7	9.3

FIGURE 42—Drop-off index related to age (boys).



AGE	7	8	9	10	11	12
MEAN	176	168	173	173	162	170
NUMBER	19	24	23	25	13	9
σ	16.78	18.30	18.05	16.91	12.25	11.96

Figure 43—Five-minute step test vs. age (boys).

The lying diastolic pressure (Figure 37) rises from 59 mm. Hg to 65 mm. Hg in a corresponding manner, and the standing diastolic pressure (Figure 38) from 68 to 70 mm. Hg. The lying pulse rate (Figure 39) declines from 89 to 81 during this same age span. The standing pulse rate (Figure 40) slows from 107 to 103.5. The Schneider index (Figure 41) rises from 6 points to 12 points over the span from 7 to 17 years.

The drop-off index (600-yard time / 60-yard time) (Figure 42) is highly related to circulatory fitness, that is, oxygen intake capacity in maximal work. It improves slightly with age, but there is virtually no reduction from 9 to 13 years, corresponding to the oxygen intake curves given in Chapter VII.

The 5-minute step test (Figure 43), based on the sum of recovery pulse rates 1 to 1½, 2 to 2½, and 3 to 3½ minutes after the exercise, shows a steady improvement from 176 at 7 years of age to 162 at 11 years of age, after which there is a dip (fatigue effect) in the curve at 12 years.

Several other cardiovascular tests were eliminated because of poor reliability, including the progressive pulse ratio and the Barach index, but both of these show the "fatigue effect" at 13 and 12 years, respectively.

Plates I, II, and IX illustrate some of the procedures reported in this chapter.

IV

THE EFFECTS OF TRAINING ON THE PHYSIQUE OF BOYS

Perhaps because physique is the most tangible manifestation of growth in children, parents are unusually interested in this aspect of their child's physical fitness. Frequently, their questions concern deviations from "the normal" in height, weight, soft-tissue distribution, body proportions, and posture. They are equally concerned with the influence of maturation on growth rate, possible adult form, the influence of build on their child's performance, and the relation between physique and behavior. The answers to these questions, at times of necessity in tentative terms, may be drawn from the wealth of literature on child growth and development; but where marked "deviations from the normal" are in evidence and where the question "To what extent would physical training produce changes in the desired direction?" is put, the documentary cupboard is remarkably bare. It is precisely for this reason that the major portion of the present chapter deals with the effects of training on physique.

In most instances, the techniques of analysis do not warrant the claim that the observed changes are caused by training. However, in the absence of evidence showing comparable morphological changes combined with changes in motor performance in individuals who have not undergone training, the possibility of causality is not excluded.

Five general observations may be derived from the studies reported.

1. Quite often, averaging group data serves to minimize and conceal individual changes, which become apparent only when individual cases are studied.

2. Training of greater intensity than is commonly believed necessary is required for changes in physique to occur.

3. The effects of training are greater when such training is undertaken in small groups and the training is directed toward specific developmental objectives.

4. Linear aspects of build tend to maintain a moderately high degree of constancy, but such aspects of build as are dominated by soft tissues are less constant.

5. Relations between physique and performance are slight during prepubescence but tend to increase over the adolescent years.

Assessment of Physique

The classification of somatotypes used with young boys is essentially that of Sheldon-Stevens-Tucker (143), with slight modifications made by Cureton (31, 35). In addition to the subjective flesh rating, an objective assessment is made with the reciprocal of the ponderal index (height divided by cube root of weight) along the base of the somatotype triangle (endomorphy-ectomorphy) and the sum of four strength tests representing mesomorphy on the vertical axis.

There is some question of the applicability of Sheldon's threefold classification of somatotype to children. A recent factorial study of children's body measurements and ratios showed an endomorphy-like component characterized by bulkiness, prominent girths (especially of the upper arms), broad hips, narrower shoulders and thick fat covering, and an ectomorphy-like component characterized by a lean frame and attenuated limbs; but no mesomorphy-like component has emerged from this or other analyses of children's data (11). The difficulties involved in relating body build to strength in boys have been noted by Jones (82), while Parnell (124) has found an objective rating of muscularity to be the least constant over a three-year period (7 to 10 years).

A third growth factor from the above analysis is one related to dysplastic growth in vertical dimensions, characterized by disproportionate development of the trunk and legs. Although the factor is clearly present in our data from children 7 to 11 years old, the ratio trunk length / leg length is one of the least constant over the adolescent period (68).

The use of scaled factor types for children at the various developmental stages appears to be the next logical step in assessing the physique of children.

Constancy of Physique

The degree to which childhood physiques retain their distinguishing characteristics in adulthood is a matter of both theoretical interest and practical concern, and one on which there is little agreement. Extreme views range from Tanner's (151) claim that adult somatotype may be predicted with accuracy from the age of five or even earlier, to that of Hunt and Barton (75) in which a broad range of early physiques is seen as leading to outwardly similar adult forms through the influence of alternative developmental patterns. Here, one must distinguish clearly between ratings of the genotype and the phenotype, those of the latter being indeed subject to marked variations due to changes in the quantity and/or density of the soft tissues associated with nutritional (104) and training (41) influences. Pertinent to the case in point is Parnell's (124) example of an "exceptional change" in somatotype estimate, wherein a boy rated 4½ 4½ 1 at age 7

became a 6 3½ 1 at 11 years. Such changes, albeit more commonly in the opposite direction (less endomorphy and more mesomorphy) are by no means unusual in studies involving persistent, rigorous training. These changes imply that the phenotype, as assessed subjectively, has changed; but of greater general consequence to those concerned with the appraisal of physical fitness are the associated changes in strength and motor performance accompanying the altered soft tissue measurements. Concern for these correlative items probably leads workers in physical education to a rating bias in the direction of the phenotypic aspects of build, whereas the reverse is probably true of those engaged in constitutional research. In any case, it leads to the question of whether it is even possible to rate accurately the endomorphic component as a facet of the genotype, since transient fat may easily be mistaken for endomorphy.

Parnell (124) typed 72 children twice, four years apart, using measurements of skin-fold fat, bone, muscle girth, height, and weight to estimate the phenotype. The results of the correlation analysis showed only moderately high relations between the initial and final estimates. Linearity showed the highest correlation (.7), fat the next highest (.6 to .7), and muscularity the lowest (.5 to .6). A similar study of our own Illinois data by Herron (68), in which 11 body ratios from 26 boys measured and photographed 5 years apart were analyzed in terms of group status (rank-order correlation) and mean differences, also showed greater constancy in the ratios associated with linearity (height × 100 / 6 × transverse chest, and height / cube root of weight). These relations are shown in Table 1. Thigh

TABLE 1

Mean, Significance Values, and Rank-Order Correlations of Body Segments Measured Five Years Apart (Herron, 1960)

Physique Ratio	M_1	M_2	t	p	ρ	p
Shoulder width / hip width	1.35	1.41	3.410	(.01)	.408	(.05)
Height × 100 / 6 × chest breadth ...	109.2	108.0	−1.307	(*ns*)	.852	(.01)
Chest depth / chest breadth	0.723	0.687	−2.681	(.05)	.482	(.05)
Thigh girth / knee width	4.67	4.89	3.698	(.01)	.574	(.01)
Arm span / height	1.003	1.019	5.820	(.01)	.751	(.01)
Height / cube root of weight	13.01	13.11	0.511	(*ns*)	.718	(.01)
Bust height / picture height	0.480	0.472	−2.955	(.01)	.416	(.05)
Arm length / leg length	0.661	0.660	−0.756	(*ns*)	.676	(.01)
Foreleg length / thigh length	1.164	1.182	1.559	(*ns*)	.375	(*ns*)
Upper arm length / forearm length .	1.201	1.149	−3.988	(.01)	.350	(*ns*)
Leg length / trunk length	1.703	1.681	−1.072	(*ns*)	.337	(*ns*)

NOTE.—Degrees of freedom: for t, $N - 1 = 25$; for ρ, $N - 2 = 24$.

girth / knee width, a ratio which is related to the endomorphic component, also remained fairly constant. The ratios related to length of lower over upper segments of the limbs and the ratio of leg length over trunk length were least constant. There appears to be a moderately high constancy in those ratios which reflect general growth, and less in ratios related to the growth of specific parts.

Changes of the kind listed are frequently overlooked in group studies where averages only are considered. The somatotype photographs of A.H., taken at ages 9 years and 5 months, 10-5, and 14-4, show a marked shift in the direction of ectomesomorphy in a boy with some endomorphic characteristics at age 9-5 (Plate XIII). During the course of an interview with the subject's parents after the first records were taken, the poor condition of his feet and legs, low endurance and moderately protuberant abdomen were noted. Special emphasis was given these areas in an individual training program of corrective and developmental activities during the ensuing year. The interest engendered in the subject, together with the improvement in his basic motor abilities, effected a radical change in his attitude toward, and participation in, sports and training. While the case is an extreme one, it serves to illustrate that a combination of changes in physique, improvements in performance and a greater disposition to participate in physical activity are possible under favorable conditions of adequate guidance, parental cooperation and sufficient motivation on the part of the subject. The complete data for this subject are presented in Appendix C. It may be noted here that A.H. was rated a 4 4 4 at age 9-5, a 3½ 4 5 at 10-5, and a 2½ 3½ 4½ at 14-4.

Relations between Physique and Performance

Adult physique is known to influence performance, at least insofar as high-level performance is concerned (5, 29, 90). Even with normal young men, a high endomorphy component is negatively related to endurance performance (49), as is skin-fold fat (88), while the reverse applies in the case of mesomedials (49).

Espenschade (58) has studied the relations between anthropometric measurements and indices and power tests (60-yard dash, standing broad jump, and jump and reach) in boys 12 to 17 years old. Height correlated approximately .40 with the 60-yard dash and broad jump at /13 years, slightly less at 15 years, and not at all at 17 years. These decreasing relations were considered due to a common growth factor which is no longer operative after maturity is reached. Jump and reach bore a reverse relation to height, being more closely related to the latter at older than at younger ages. An increasing relation between the ratio stem length / height and the power tests was shown with increasing age, suggesting that body build may become a factor of increasing importance as growth in height and

weight ceases. The ratio bi-iliac width /standing height correlated negatively with all the motor tests at 13 years and positively at 17 years, indicating that boys of more slender build excel in performance at 13, whereas those of more stocky build are superior at 17.

With the height of boys of 6 to 17 years held constant, Asmussen (7) found that age had a positive influence on running, vertical jump, and acceleration. This maturation influence was slight in tests of vital capacity and maximum breathing capacity, more pronounced in strength tests, and most marked in those in which neuromuscular coordination in voluntary movements can be expected to develop late, for example, in elbow flexion as compared with elbow extension, in acceleration as opposed to simple running. These differences were attributed to a gradual qualitative development of the neuromuscular system with age.

Total static strength was found by Jones (82) to correlate .34 with an estimate of mesomorphy in boys 17.5 years of age, whereas the correlation of strength with ectomorphy was small and negative, and with endomorphy it correlated zero. Weight correlated with strength .52, and with height, .33. The correlation coefficients relating body build to motor ability in the Illinois (59) data tend to be low in prepubescence and tend to increase with age. In Eynon's (59) study of 72 boys 6 to 12 years of age, endomorphy was correlated negatively with agility and positively with static strength. In both cases, the coefficients were low but significant. Mesomorphy correlated positively with agility, whereas ectomorphy was not related to any of the motor abilities (Table 2). Using the Iowa Brace test as the index of motor ability with 107 older boys (10 to 13), Voisard (159) found ectomorphy to be posi-

TABLE 2

Correlations between Somatotype Ratings and Motor Fitness Performances (Eynon, 1958)

Variable	*Endomorphy*	*PE*	*Mesomorphy*	*PE*	*Ectomorphy*	*PE*
Total strength	.297	±.092	—.050	±.101	—.075	±.101
Strength / weight	—.284	±.093	—.032	±.102	.226	±.096
Standing broad jump	—.254	±.095	.185	±.098	.279	±.094
Vertical jump	—.128	±.099	.147	±.099	.071	±.101
Endurance hops	—.252	±.095	.062	±.101	.199	±.098
Floor push-ups	—.222	±.096	.180	±.098	.127	±.099
Chinning	—.212	±.097	.029	±.105	.278	±.094
Progressive balance	—.215	±.097	—.095	±.101	.121	±.099
Illinois agility run	.332	±.090	—.311	±.092	—.132	±.099
Trunk flexion	.202	±.096	—.071	±.101	—.125	±.101
Trunk extension	.146	±.099	.098	±.101	—.032	±.106

NOTE.—r = .292 for significance at .05 level, .376 for .01 level.

Table 3

Correlation Coefficients between Somatotype Component Ratings and Iowa Brace Test Scores (Voisard, 1954)

	r	*PE*	η	*SE*	*Corrected* η
Endomorphy	—.499	±.049	.631	±.058	.602
Mesomorphy	.153	±.064	.239	±.091	.032
Ectomorphy	.434	±.053	.524	±.071	.479
Ponderal index	.350	±.057	.512	±.072	.469

tively correlated (.43) and endomorphy negatively correlated (—.50), whereas mesomorphy was unrelated (Table 3). The absence of strength and power items in the Brace test may account in part for lack of relation with the mesomorphy component. Both product-moment and η correlation coefficients, together with probable and standard errors, are shown in Table 3.

A second approach to the matter of build-performance relations embodies the use of factorial techniques. In a comprehensive analysis of 37 anthropometric measurements and indices, ten motor tests, and age (range 6 to 11 years), three motor factors (power, endurance, and dynamic shoulder strength) were found to be essentially unrelated to the morphological variables after the effects of gross body size had been partialed out by rotational procedures (11). Of some interest in this connection is the fact that endurance, the acquisition of which is often assumed to be the result of maturation and developmental processes, was found to be unrelated either to age or to the morphological variables.

Performance would seem, then, to be relatively free from the influence of physique in the prepubertal years, but the relation becomes more intimate at later age levels.

Effects of Sports and Training on Physique

Investigation of the effects of sports and training on physique and growth is beset by many unique problems related to maturation level, nutritional status, seasonal variations, and various sociological and psychological influences. The major problem is that of isolating the growth factor associated with advancing chronological age and separating it from the longitudinal effects of the training. Ideally, trained and nontrained groups matched on the basis of physiological age, with nutrition, rest, motivation, and extracurricular activities all controlled, would be compared. Until such experiments are conducted, it will be extremely difficult to say with great precision what improvements are attributable to physical education programs. A less precise, but practical, technique is to measure changes with respect to a

reference group which has had no specific training and whose average measurements and scores are plotted for each year of chronological age. Individuals may then be compared with average trends for their age groups.

Muscle Girth and Training

Araki (4) studied six boys whose upper bodies were markedly underdeveloped. The six subjects underwent a 21-week period of training consisting largely of medicine-ball work, meeting once each week and practicing daily at home (30 minutes) under the supervision of their parents. Biceps, chest (normal and expanded), and abdominal girths all tended to increase, but less, relatively, than flexibility, static strength, and muscular endurance in the shoulders. The interpretation of girth measurements is always rendered complex by their failure to differentiate between muscle and fatty tissue. Graphs plotted weekly for these subjects showed a lag in the girth increases, most of the increases occurring toward the end of the 21 weeks.

In a well-motivated group of five boys who participated in a 10-week program of skipping (1½ hours each Saturday and 15 minutes each day at home), Powell (129) demonstrated clearly defined differential changes in muscle girths associated with this specific type of training (Table 4). The increases in calf girth (mean, 1.3 inches) are unusually large for such a short period of training and were accompanied by decreases in gluteal girth and abdominal girth and by increases in biceps and chest girths, and in the compound measure of expanded chest minus abdominal girth (mean, 2.50 inches).

Adipose Tissue and Training

The Sports-Fitness Summer School has provided some insight into the conditions under which changes in skin-fold fat may and may not occur. The skills-centered program was accompanied quite often by increases in the sum of the six folds measured (cheeks, abdomen, hips, gluteal, front and rear thigh). The mean increase in total fat of 69 boys in the 1955 program was 28.6 mm. (95.0 to 123.6 mm.) (114). Part of the increase is probably due to the increased opportunities for between-meal snacks coincident with the summer vacation, but it is quite evident that the activity program contributed little in providing a comparable source of energy expenditure. In the 1956 program, with the introduction of repeat 600-yard runs and muscular endurance items, the pre- and post-training sums of total fat were 121.1 and 121.3 mm., respectively. Fifteen volunteer subjects from the latter program, who supplemented the normal training with 20 to 30 minutes of additional endurance training per day, showed a mean decrease of 9.3 mm. (133.0 to 123.7 mm.).

TABLE 4

Changes in Bone, Muscle, and Fat Measurements during 10 Weeks of Rope Skipping (Powell, 1957)

	Subject A		Subject B		Subject C		Subject D		Subject E	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
Age (years, months)	10, 8	11, 3	10, 0	10, 7	9, 10	10, 5	10, 11	11, 6	11, 3	11, 10
Height (inches)	60.50	62.00	55.00	55.75	55.50	56.50	58.75	60.00	59.00	60.00
Weight (pounds)	92.50	91.00	85.00	88.00	76.00	81.00	95.00	101.00	131.50	132.00
Somatotype	3½3½5	3½3½5	5½43½	5½43½	4 4½ 4	4 4½ 4	5 4 3	5 4 3	7 3 1	7 3 1
Crampton index	P_1	P_2	P_1	P_1	P_1	P_1	P_1	P_1	P_1	P_1
Reciprocal of ponderal index	14.35	13.75	12.50	12.50	13.10	13.05	12.84	12.85	11.60	11.80
Expanded chest minus abdominal girth	5.50	6.50	3.10	5.25	4.80	6.50	4.50	7.25	0.08	3.00
Right scaphoid deviation (cm.)	1.58	1.55	1.10	1.25	1.30	1.10	1.40	1.27	7.00	0.30
Left scaphoid deviation (cm.)	1.40	1.50	0.95	1.37	1.70	1.50	0.90	1.00	0.60	0.60
Right arch angle (degrees)	33.50	43.00	12.00	24.00	33.00	33.00	5.00	15.50	7.50	12.00
Left arch angle (degrees)	37.00	42.50	18.00	29.00	21.00	22.00	14.00	22.00	12.50	28.50
Right big toe angle (degrees)	19.00	23.00	12.00	19.50	19.00	19.00	17.00	13.50	22.00	16.50
Left big toe angle (degrees)	25.00	22.00	15.05	14.00	15.50	14.00	17.00	10.00	16.50	15.50
Right scaphoid height (cm.)	4.60	4.60	3.00	3.80	4.10	4.10	3.00	4.00	2.50	4.00
Left scaphoid height (cm.)	4.50	4.80	3.20	4.00	3.30	3.60	3.10	3.60	2.50	3.50
Right outer malleolus height (cm.)	5.30	5.30	5.50	5.20	5.00	5.00	5.80	5.70	5.50	5.50
Left outer malleolus height (cm.)	5.00	5.90	5.70	5.80	5.70	5.60	5.50	5.50	5.50	5.00
Right inner malleolus height (cm.)	7.00	7.00	6.70	6.80	6.00	6.00	6.70	6.50	7.20	7.80

(a) Pretraining and post-training (4 months) posterior view of feet (J.C.)

(b) Pretraining and post-training (4 months) medial view of right foot (J.C.)

(c) Pretraining and post-training (4 months) posterior view of feet (P.D.M.)

(d) Pretraining and post-training (4 months) posterior view of feet (B.L.)

Plate III—Case studies of changes in feet.

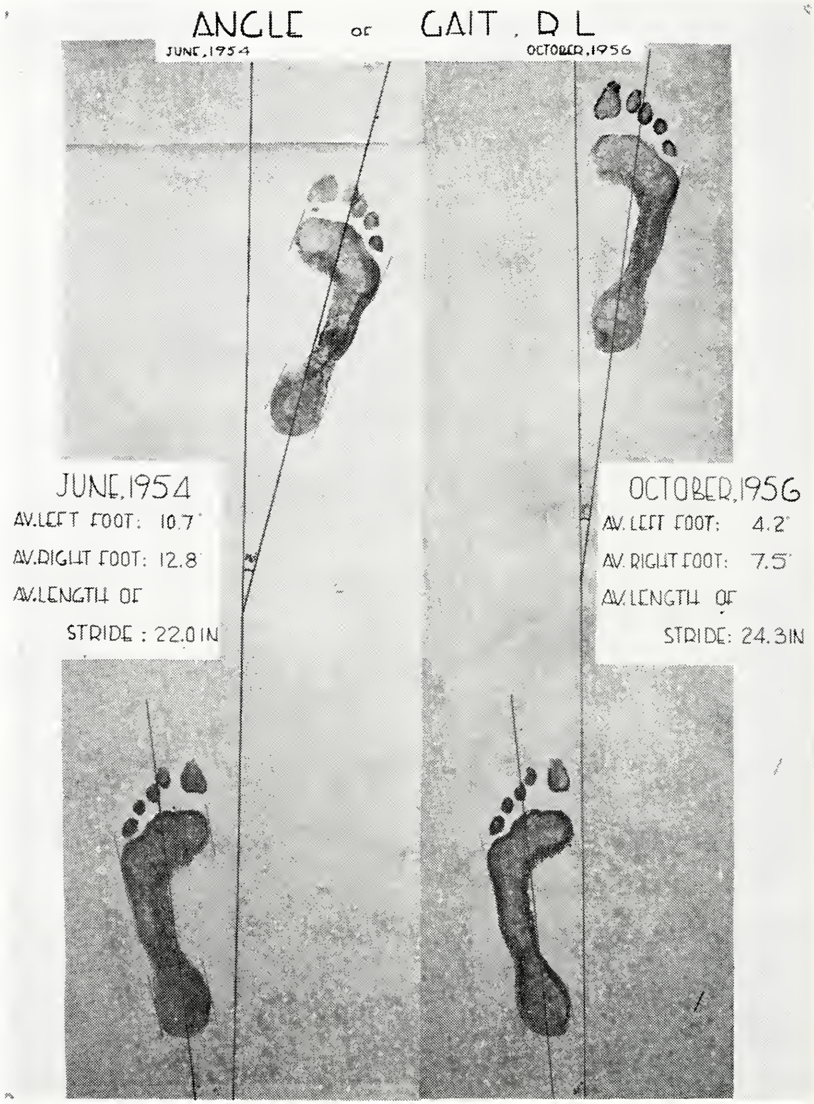
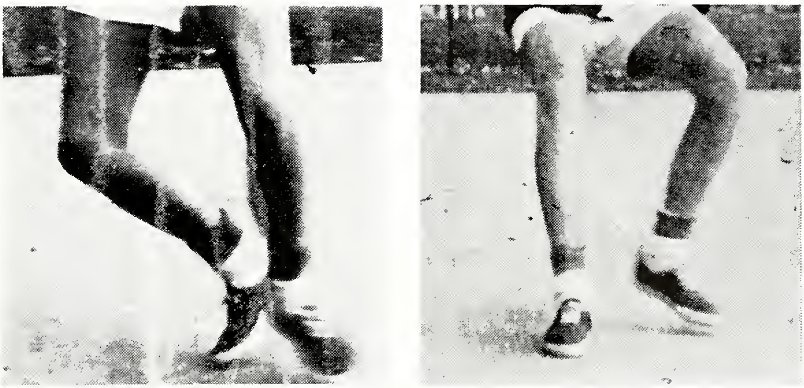
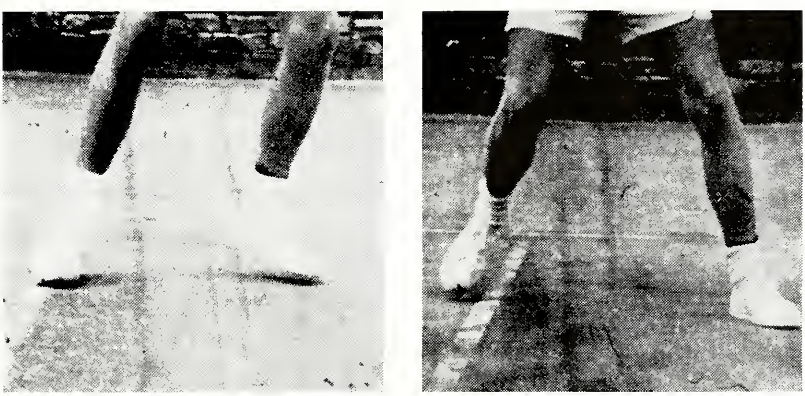


Plate IV—Pretraining and post-training (2 years and 4 months) walking prints of R.L., showing decrease in angle of gait.

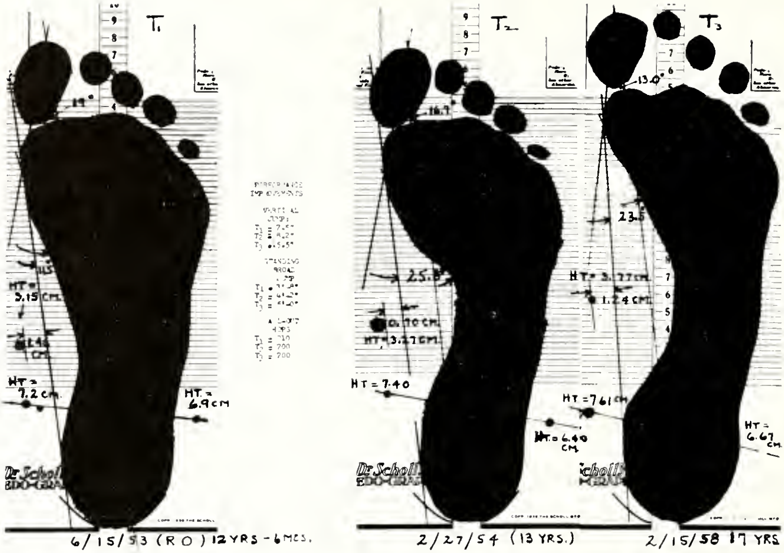


(a) Pretraining footwork in tennis, showing marked splaying of feet (R.L., June, 1954).



(b) Post-training footwork in tennis, showing decrease in splaying of the feet (R.L., October, 1956).

Plate V—Case study of changes in footwork in tennis.



(a) Pretraining, post-training (6 months) and follow-up (4 years) footprints of R.O. (right foot).

(b) Pretraining, post-training (6 months) and follow-up (4 years) footprints of R.O. (left foot).

PLATE VI—Case study of changes in footprints.

Left inner malleolus height (cm.)	6.00	6.00	6.70	6.80	5.50	5.70	5.70	6.40	6.00	7.80
Shoulder width (inches)	13.00	13.50	11.50	12.25	11.50	13.00	12.50	13.00	11.00	11.00
Chest girth, normal (inches)	26.50	26.50	26.50	27.00	25.50	26.25	26.00	27.00	30.90	31.50
Chest girth, inflated (inches)	29.50	29.50	28.50	29.75	28.00	28.50	28.50	30.25	33.80	34.50
Chest girth, deflated (inches)	26.00	26.00	26.00	26.50	25.00	25.00	25.50	26.00	31.20	29.75
Chest expansion (inches)	3.50	3.50	2.50	3.25	3.00	3.50	3.00	4.25	3.60	4.75
Arm span (inches)	60.50	61.00	53.50	53.75	55.00	56.00	57.00	58.00	60.25	61.00
Abdominal girth (inches)	24.00	23.00	25.50	24.50	23.20	22.00	24.00	23.00	33.00	31.50
Chest breadth (inches)	8.75	9.25	8.50	9.00	9.00	9.25	9.00	9.50	10.40	10.80
Chest depth (inches)	6.50	6.75	8.50	8.50	5.80	6.00	6.40	6.50	6.45	7.00
Ankle girth (inches)	8.00	7.75	7.50	7.25	7.50	7.25	8.00	8.25	8.70	9.00
Hip width (inches)	9.50	9.50	9.00	9.00	9.00	9.00	9.60	9.75	12.30	13.00
Gluteal girth (inches)	30.75	28.75	30.75	29.50	28.00	27.25	31.00	31.00	33.40	33.75
Calf girth (inches)	10.00	11.75	10.50	11.75	10.00	11.25	12.00	13.25	13.90	15.00
Biceps girth (inches)	7.90	8.25	8.20	8.50	7.50	8.00	9.00	9.50	10.90	10.90
Thigh girth (inches)	18.50	17.50	18.50	18.00	17.00	17.00	18.50	19.50	20.90	21.50
Fat on cheeks (mm.)	18.00	15.00	21.00	20.00	18.00	15.00	22.00	19.00	20.00	19.00
Fat on abdomen (mm.)	20.00	20.00	34.00	32.00	12.00	7.00	25.00	23.00	42.00	37.00
Fat on hips (mm.)	35.00	23.00	37.00	32.00	30.00	22.00	38.00	35.00	38.00	35.00
Fat on gluteals (mm.)	38.00	38.00	40.00	41.00	31.00	33.00	37.00	34.00	30.50	30.00
Fat on front thigh (mm.)	26.00	22.00	40.00	41.00	22.00	22.00	32.00	36.00	41.00	39.00
Fat on rear thigh (mm.)	32.00	32.00	45.00	40.00	35.00	33.00	32.00	32.00	27.00	27.00
Total fat (mm.)	157.00	140.00	217.00	206.00	148.00	132.00	186.00	179.00	198.50	187.00

The inefficacy of gross weight as a guide to fluctuation in fat and tissue density may be seen in the weight changes in the boys taking part in the 1956 program who gained or lost more than 10 mm. of total fat. Those who gained 10 mm. or more showed a mean increase in weight of 4.80 pounds, whereas those who lost comparable amounts of fat increased 4.02 pounds. Weight in itself is a poor guide and gives little indication of changes in fat unless the changes are very gross. Muscle bulk is usually added with heavy resistance training, so that body density, and hence weight, increases, even though fat may be lost.

The rope-skipping, to which reference has been made, resulted in a mean total fat loss for the five subjects of 12.5 mm. (range 7 to 17 mm.) (129). The greatest losses occurred on the hips and abdomen.

Running and muscular endurance exercises resulted in marked fat losses in a single subject A.H. over a period of a year. A.H. was initially rated a P_1 on the Crampton scale (9 years and 5 months) and would normally have anticipated a total fat loss of 7 mm. in the ensuing year. A loss of 57 mm. in A.H. was associated with an increase in height of 2.0 inches (expected gain, 2.0 inches) and a weight loss of 0.8 pounds (expected gain, 8 pounds). The changes in somatotype accompanying such changes have been referred to earlier. When changes of this nature are associated with improvements in motor performance, they are considered favorable adjustments to the training undertaken.

Changes in the Feet

The big-toe angle, arch angle, internal and external malleolus height, and the height of the scaphoid bone are measures used to reflect the structure and alignment of the foot. Persistent exercising designed to strengthen the longitudinal and transverse arches of the feet is frequently associated with a shift in the alignment of the feet from a pronated (weak) to a supinate (strong) position, together with increased flexibility in the ankles and improved jumping ability in the vertical and standing broad jumps.

A group study of the effects of an 8-month tumbling and trampoline program on the feet of 14 boys 5 to 11 years of age produced minor changes in the structure and alignment of the feet, but resulted in considerable improvements in ankle flexibility and vertical jump height (122).

Of greater interest are the following case studies in which morphological and/or functional impairment was evident at the onset of training. The first three subjects participated in a program consisting of running, skipping, and corrective exercises for the feet and legs. The program was conducted for a 22-week period, with formal meetings once each week (2 hours) and daily training for 20 minutes under the supervision of the parents. In the first two subjects, improvements occurred in both alignment and function; in the third, virtually no changes occurred over the training period (Table 5) (129).

TABLE 5

Changes in the Feet of Three Boys (Herron, 1960)

	J.C. (11 YEARS)					P.D.M. (13 YEARS)					B.L. (10 YEARS)				
	Raw Score		*Standard Score*			*Raw Score*		*Standard Score*			*Raw Score*		*Standard Score*		
	T_1	T_2	T_1	T_2	Diff.	T_1	T_2	T_1	T_2	Diff.	T_1	T_2	T_1	T_2	Diff.
Left external malleolus height (cm.)	5.3	6.1	29	46	+15	6.7	7.35	59	71	+12	6.50	6.55	60	60	0
Right external malleolus height (cm.)	5.9	6.0	42	44	+ 2	6.2	6.85	48	61	+13	6.60	6.55	60	60	0
Left interior malleolus height (cm.)	5.5	6.05	29	35	+ 6	7.4	7.75	62	86	+24	5.50	5.65	22	26	+ 4
Right internal malleolus height (cm.)	5.6	6.0	29	34	+ 5	7.5	7.75	66	86	+20	5.90	5.95	30	31	+ 1
Left scaphoid height (cm.)	0.7	2.35	..	..	..	3.1	3.1	..	..	..	1.8	2.0	..	..	..
Right scaphoid height (cm.)	1.4	2.15	..	..	..	3.1	3.5	..	..	..	2.0	2.3	..	..	..
Left scaphoid deviation (cm.)	1.7	2.1	..	..	..	1.65	1.60	..	..	..	1.6	1.2	..	..	..
Right scaphoid deviation (cm.)	1.4	1.65	..	..	..	1.45	1.35	..	..	..	0.9	1.3	..	..	..
Left big toe angle (degrees)	18.0	14.5	47	56	+ 9	18.0	7.0	47	50	+ 3	23.0	26.0	32	25	− 7
Right big toe angle (degrees)	18.0	11.0	47	66	+ 9	22.5	16.5	37	51	+14	24.0	26.0	31	26	− 5
Left arch angle (degrees)	12.0	39.5	33	51	+14	42.0	43.5	54	55	+ 1	18.0	15.0	38	36	− 2
Right arch angle (degrees)	11.0	28.5	31	44	+13	43.5	46.5	55	58	+ 3	10.0	15.0	30	36	+ 6
Vertical jump (inches)	11.5	12.0	53	58	+ 5	15.0	18.5	78	100	+22	11.5	11.5	55	55	0
Standing broad jump (inches)	58.0	63.0	45	58	+13	60.0	76.0	38	85	+47	56.0	57.5	48	51	+ 3
Progressive balance beam (points/30)	21	20	60	55	− 5	12	24	35	60	+25	11	13	35	40	+ 5

Subject J.C. (11 years)

An examination of the foot photographs of this subject is helpful in interpreting the changes in morphology revealed by the anthropometric measurements (Plate III [a] [b]). There is clearly a changed placement of the feet to be considered, but the photograph of the medial side of the right foot shows a noticeable difference in outline from T_1 to T_2. Although the splaying of the feet in the T_1 series makes an accurate assessment impossible, there is a slight suggestion of a straightening of the Achilles tendon in both legs.

The shadow on the T_2 photograph of the medial side of the right foot, running from the internal malleolus toward the apex of the longitudinal arch, represents a rather odd bone structure. The shadow coincides with the edge of a bony protuberance.

The malleoli showed the greatest change over the period of training—the left external increased in height by 0.8 cm.—bringing about greater equality between the morphology of the left and right feet. The scaphoid heights ($+1.65$ cm. in the left and $+0.75$ in the right) and arch angles also improved ($+27.5°$ in the left and $+17.5°$ in the right).

Performance improved most in the broad jump (an increase of 5 inches) but the 600-yard run gave the boy some difficulty. The condition of this subject's feet had precluded persistent and rigorous participation in sports and training, with the result that there was a deficiency in the capacity to control total body movements (i.e., where dynamic activity was involved). As might be expected in these circumstances, with poor feet and meager strength, the boy demonstrated poor endurance.

Subject P.D.M. (13 years)

This subject showed an improvement in every morphological and performance measurement. The boy was assigned to the program because of an apparent imbalance between the development of the left and right feet. There was no pronation. What is more noticeable from the foot photographs is the advanced development of the bones of the ankle joint and the slight displacement of the Achilles tendon (Plate III [c]). Both these characteristics are still evident in the T_2 series.

The greatest change was in the height of the external malleoli ($+0.65$ cm. in each foot). While changes in other morphological measures were all in a favorable direction, none of them is sufficiently large to suggest more than growth effects.

Performance improved in chins, vertical jump, dips, balance beam, and broad jump. The addition of 16 inches in the broad jump and 3½ inches in the vertical jump suggests improved functional power in the feet and leg muscles. The doubled score on the balance-beam test is indicative of improved balance.

Because the subject had to miss the first part of the weekly supervised activity, he did more treadmill running and less rope-skipping than the other members of the group.

Subject B.L. (10 years)

This subject worked very hard in the rope-skipping part of the program. He was capable of doing over one thousand skips without stopping. Although his capacity for this type of work increased tremendously over the course of the training program, the foot photographs show little suggestion of any change in foot morphology (Plate III [d]). The actual measurements confirm these observations. The malleoli of both feet have changed only to the extent which might be expected with growth. Changes in big toe and arch angles are insignificant. There is a slight improvement in the scaphoid height of both feet, but it is hardly sufficient to be considered a training effect.

Subject R.L. (16-3 to 18-8 years)

This case involves certain interesting changes that occurred in a high school boy during the course of a training experiment conducted over 2½ years. The study began in chance fashion when the boy, at the age of 16-3 years, was observed playing tennis. His strokes were unusually fluent, but footwork and court movements in general exceptionally poor. He was noted as having widely splayed feet. Physique, motor, and cardiovascular tests in the laboratory showed that his motor abilities were about average, as were the results of his cardiovascular tests. He was of medial build with a fat covering slightly above average. Using the method adopted by Dougan (56) for purposes of comparison, walking footprints were recorded. Dougan reported average angles of gait for high school boys as 4.87° for the left foot and 7.25° for the right. Corresponding measurements for the present subject were 11.0° and 13.0°.

Wide out-toeing (or splay feet) has been attributed to a variety of influences, among them, age, stoutness, fatigue, uneven surfaces, anatomical variations as found in the degrees of femoral, tibial, and malleolar torsion, and so on. Elftman (57) has considered the possibilities of developmental changes in torsion due to external forces but concluded that "the final factor which must be evaluated is the innate capacity of bones themselves to respond to the external forces or to proceed counter to them. . . . More direct methods of experimentation would be advantageous, if possible of performance" (94, p. 264).

Functionally, the problem concerns the advantage of using the feet parallel to the line of body motion for the most effective leverage of action on the one hand, and the advantage of out-toeing for lateral stability on the other. What Elftman meant by "direct methods of experimentation" is not entirely clear; but in terms of human performance, the most direct method appeared

to be whether the angle of gait could be changed markedly. A training program was conducted for over two years, the emphasis in the first year being given to corrective and conditioning exercises for the feet and legs designed to control the range of motion in the hip joints during normal movements. An intensive program of activities involving walking, running, and jumping followed during the second year in order that the changes observed might become habitual.

TABLE 6

Training Data for R.L.—Physique and Motor Tests

Test Item	BEFORE (*1954*)	AFTER (*1956*)	CHANGES *Standard Score*	*Per Cent*
Age (years, months)	16, 3	18, 8	..	....
Height (inches)	72.6	73.6	..	+ 1.38
Weight (pounds)	150.25	155.0	..	+ 3.12
Expanded chest minus abdominal girth (inches)	+4.4	+5.4	..	+22.8
Adipose (fat) (mm.)	146	77	..	−47.2
Vital capacity (cubic inches)	−70	−12	+24	....
Abdominal girth (inches)	29.0	29.7	..	+ 2.41
Visual reaction time (seconds)	0.297	0.243	+14	....
Auditory reaction time (seconds)	0.255	0.240	+ 3	....
Combined reaction time (seconds)	0.251	0.233	+ 5	....
Agility run (seconds)	19.5	16.9	+31	....
Chinning (number)	3.0	6.5	+19	....
Dipping (number)	3.0	12.5	+39	....
Left grip (pounds)	106	125	+18	....
Right grip (pounds)	88	88	0	....
Back lift (pounds)	320	440	+30	....
Leg lift (pounds)	360	660	+51	....
Total (sum of four) (pounds)	874	1313	+46	....
Strength/weight	5.84	8.49	+45	....

The walking prints after the second year gave angles of gait of 4.2° for the left foot and 7.5° for the right, both of which are close to the norm for high school boys (Table 6 and Plate IV). Motion films were taken on the tennis court before and after the training, stills from which are shown in Plate V. R.L. reached the finals of the Illinois State High School Championships in his senior year (18 years).

Subject R.O. (12-6 to 17-2)

Analysis of this subject's physical fitness tests in 1953 revealed markedly pronated feet, low arches, and poor performance scores on all tests involv-

TABLE 7

Foot and Performance Changes in R.O.

	JUNE, 1953 T_1		OCT., 1953 T_2		FEB., 1958 T_3	
Test	*R.S.*	*S.S.*	*R.S.*	*S.S.*	*R.S.*	*S.S.*
Left arch angle (degrees)	9.0	5	25.0	27	16.0	5
Right arch angle (degrees)	11.5	6	25.8	28	23.5	18
Left great toe angle (degrees)	20.0	30	20.5	26	18.0	10
Right great toe angle (degrees)	19.0	40	16.7	51	13.0	35
Left scaphoid deviation (cm.)	1.64	13	0.58	62	1.00	20
Right scaphoid deviation (cm.)	1.46	21	0.70	55	1.24	11
Standing broad jump (inches)	44.0	16	50.0	28	60.0	20
Vertical jump (inches)	7.5	15	8.0	25	15.5	27
Illinois agility run (seconds)	25.2	14	23.8	28	23.0	18

ing use of the feet and legs (T_1, Table 7). The left foot showed 1.64 cm. in scaphoid deviation and the right foot 1.46 cm. A series of corrective exercises, together with running and endurance hopping, were performed over a four-month period, resulting in considerable improvement both in the alignment of the feet and in the functional tests (T_2). The arch angles in both feet more than doubled, while the degree of pronation as indicated by the scaphoid deviation was greatly lessened in both feet (Plate VI). The subject was reexamined 4½ years later (T_3), at which time some retrogression had occurred in the arch angle and scaphoid deviation.

Although considerable improvement had taken place in the condition of R.O.'s feet and legs, he was still below average in his school physical education classes at T_3 in terms of skill and performance. The subject discontinued the conditioning exercises after the second year, but walked to and from school each day (one mile each way) and caddied during the summer on the golf course.

V

CHANGES IN THE MOTOR FITNESS OF YOUNG BOYS ATTRIBUTABLE TO THE SPORTS FITNESS PROGRAM

This chapter deals with the training conditions (type, intensity, frequency, etc.) under which changes in motor fitness have occurred in young boys, either during the eight-week Sports-Fitness Summer Day School or in the follow-up experimental studies resulting from the associated evaluation and counseling program. In essence, its purpose is to provide quantitative data pertinent to two basic questions: What types of changes can be made in young boys? With what kinds of programs? There can be little doubt as to the fundamental nature of such questions, for upon their answers depend the dimensions and effectiveness of the school physical education program.

As is the case in analyzing and understanding other areas of physical fitness, three major problems confront those who would assess motor fitness improvements in children: first, that of identifying the factors involved in motor fitness; second, establishing normative tables for the assessment of individual abilities in those factors; and third, determining the specific training activities, time, and intensity of effort necessary to produce measurable changes in the various motor abilities.

Cureton (31) has presented a logical and statistical analysis of motor fitness tests, concluding that the six basic aspects are balance, flexibility, agility, strength, power, and endurance. That these are the main components and that specific coordinations are involved in all of them has been substantiated by the studies of McCloy (108), Carpenter (23), Latham (105), Larson (101), and Cureton (49). Interest in the measurement and development of these six motor abilities stems not only from their intrinsic value in maintaining effective communication with the environment but also from the knowledge that successful performance in any sport depends to a considerable degree on the possession of an optimal combination of one or more of them, the relative emphasis depending on the sport in question. The following description of these areas of motor fitness indicates that the primary concern is for big-muscle movements and static positions dominated by muscular energy, kinesthetic sense, and the suppleness of the major tissues and joints rather than for highly refined, skilled movements.

Balance emphasizes mental control and poise (with and without sight), the kinesthetic sense of position, and the various anatomical and physio-

logical capacities which regulate acts of balance. In gymnastics, aquatics, and in normal life such control is necessary under a great variety of conditions for skill and safety.

Flexibility emphasizes the capacity of the body to move easily to the full range of joint extension and flexion without undue restrictions in the joints and tissues. Good flexibility usually indicates that there are no adhesions, abnormal joints, injuries, or "muscle-bound" conditions of serious import. Body suppleness also indicates roughly a type of anatomical and physiological youthfulness, an important characteristic of gracefulness. People with very inextensible tissues are apt to be awkward.

Agility emphasizes the capacity for fast reaction in controlled movement where accuracy is also a feature, and the ability to handle the body quickly and precisely, not necessarily with maximum force or power, in such events as springing suddenly to the feet, dodging, jumping over a stick held in the hands, jumping through a loop formed by one hand holding the opposite foot, hitch-kicking a high object with the toe, and vaulting over a bar.

Strength emphasizes the capacity of the body, hands, or legs to exert great force. Strength in its ultimate analysis is a complex human quality involving will power, the number of fibers that can be brought into the act (neurological integration), the efficiency of the levers involved in the act, and the nutritive state of the muscle fibers involved—all to develop coordinated effort against the particular resistance. An important differentiation is that speed and endurance are not primary considerations but only the maximum force capacity is designated as strength.

Power emphasizes the capacity to release great explosive force to execute fast or sudden efforts which move the entire body with maximum effort. Physically, power is *force* $\times$ *velocity*. Both elements must be present in high-powered acts. Such physical capacity indicates a neuromuscular integration of a superior type. Events are selected in which highly specialized skill is not a major factor but which almost everyone knows how to do, such as vertical jumping, springing, and throwing weights.

Endurance emphasizes the capacity for continuous exertion with partial recovery during the exercise. Undoubtedly, there are several types of endurance, which have a large proportion of uniqueness unto themselves, such as (a) nervous endurance—emotional stability under mental strain, worry, fear, or disaster; (b) static muscular endurance; (c) rhythmic dynamic endurance; (d) endurance in acts of power; (e) long durability under monotonous work, lack of sleep, food, water, or rest—continued for days, weeks, or months; (f) specialized types of endurance specific to particular sports. Individual profiles and factor analyses involving these six components have suggested that they are fairly specific, while training studies have indicated that all are improvable with training. Although many tests of motor

Table 8

18-Item Motor Efficiency Classification Test without Apparatus

Balance

1. Diver's stance, on toes, eyes closed, 20 seconds.
2. Squat stand, 10 seconds balance.
3. Dizziness recovery, walk 10-foot line, 5 seconds after 10 turns around finger on floor.

Flexibility

4. Floor touch, knees straight (women touch palms flat).
5. Trunk flexion forward, sitting position, knees held down, forehead slowly to within 8 inches of floor (2 fists, one on top of other).
6. Trunk extension, backward, lying on front, buttocks held down, with hands behind neck, raise chin 18 inches from floor.
   Extra: (shoulder flexibility ...... inches).

Agility

7. Kneeling jump, spring to feet, hold balance for 3 seconds.
8. Jack spring, touching hands to toes at least waist high, 5 times in succession.
9. Agility 6-count exercise, squat, extend legs backward, extend legs forward, flip over, return to squat-rest position, return to standing position (6 times in 20 seconds).

Strength

10. Man lift, pick up partner of own weight and place on shoulders for carry in 10 seconds.
11. Stick body, hold 30 seconds, head on partner's knee, hands on hips.
12. Extended press-ups, from hands and toes without using elbows (women do forearm press-ups, 20 seconds).

Power

13. Standing broad jump, height plus 1 foot.

Endurance

14. Floor push-ups, 15 times (women do 30 from knees).
15. Straddle chinning, 20 times (women do 10).
16. V-sit, 60 seconds.
17. Breath-holding, 30 seconds, after running in place 120 seconds at 180 steps per minute.
18. Endurance hops, in succession, 200 up and down, 200 straddle jump, 200 alternate stride, 50 on left toes, 50 on right toes, and as many full squat-jumps as possible.

Note.—Score, number of items passed: Passing, 11 or more; superior, 17-18; good, 14-16; above average, 11-13; below average, 8-10; poor, 5-7; very poor, 0-4.

fitness are mentioned throughout the chapter, some idea of the classification of these tests may be gained from Table 8, showing Cureton's 18-Item Motor Fitness Test. The test items in each area are presented in order of difficulty; no equipment is required; and the test may be given indoors or outdoors.

Normative tables covering various test items in these six basic areas are reported elsewhere in the monograph. Apart from their usefulness in assessing individual profiles in the motor fitness test items, the age patterns indicate that the six motor abilities under reference are influenced to varying degrees by maturation processes. For example, test items dominated by strength are influenced most by growth, body type, and maturation; those dominated by flexibility, least so. Each of these areas probably has its own nature-nurture ratio, but the assessment of precise values for these ratios demands techniques of control beyond those feasible at present.

The third problem, that of assessing changes resulting from various training regimes, is the relatively unexplored one to which we now turn. The order in which the relevant studies are presented bears some explanation. First, those studies dealing with the early years of the Summer Sports-Fitness School, wherein the activity program was predominantly skill-centered, are reviewed. Second, studies dealing with the more intensive programs of recent years are considered. Third, studies related to more specialized training programs, and using as subjects boys with specific motor fitness deficiencies, are summarized; and finally, the progressive records of ten boys who participated in the summer school for several years are presented to illustrate the pattern of the case studies.

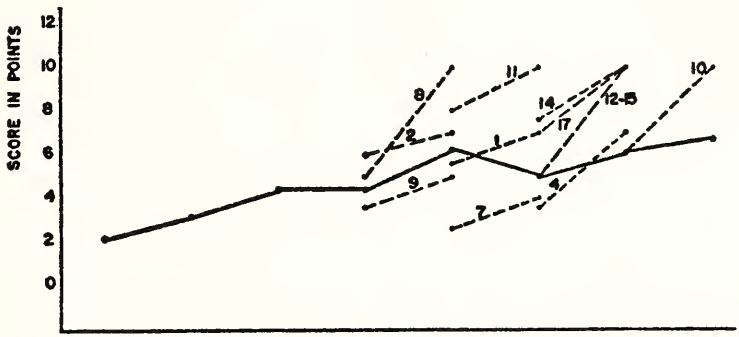
Changes in Motor Fitness Associated with Skill-Centered Programs

The acquisition of skills was the primary goal in the early years of the Summer Sports-Fitness School. Instruction was given in four major areas: (a) swimming (instruction in beginning and advanced swimming, diving, and lifesaving); (b) gymnastics (instruction in apparatus and tumbling stunts, trampoline, wire-walking, and personal defense); (c) track and field (instruction in the high jump, broad jump, shot-put, and dashes); (d) field sports (indoor and outdoor games were played, and instruction was given in the fundamentals of individual and team play strategy in softball, soccer, flickerball, basketball, volleyball, and archery). The classes met four afternoons each week (Monday to Thursday) from 1:30 to 4:30 P.M. for eight weeks.

Landry (98) followed the changes in motor fitness of a group of 17 boys 8 to 12 years of age who participated in two consecutive summer programs. The pretraining scores for each summer were compared, giving the changes resulting from one summer program and a year of normal school and extracurricular activities. The changes observed were as follows:

Balance

Of the 17 subjects, 15 showed improvement in balance-beam performance, the changes being beyond those anticipated from normal growth. Figure 44 shows these changes in relation to the normal age-performance curve. The group gain of 18 standard scores was significant at the .01 level.



AGE	5	6	7	8	9	10	11	12
N	7	4	22	28	26	30	19	7
M	2.28	3.20	4.41	4.39	6.08	5.01	6.105	6.78
σ	.854	2.51	2.47	1.62	2.54	2.34	2.02	2.29

FIGURE 44—Balance beam: comparison of pretraining and post-training test scores with age performance curve by tangents.

Flexibility

Small and nonsignificant losses were noted in the ability to flex the trunk forward (11 of 17 subjects retrogressed). The group mean loss of 0.4 inches was not significant. Eleven of the 17 subjects improved in trunk backward extension, and in nine of these the gains were greater than those expected due to normal growth changes. The group mean gain of 1.4 inches in backward extension was highly significant.

Agility

Of 17 subjects, 13 recorded poorer Illinois Agility Run times over the one-year period (Figure 45). The group mean increase in run time of 0.8 seconds was highly significant. Evidence is presented later in this chapter to indicate that adaptation to training is more readily made in the second and third years of participation in the summer program rather than the first, which may partly explain these losses in agility. It is likely, too, that the prepubertal spurt renders the nervous system highly sensitive and easily disorganized by demands for maximal speed efforts.

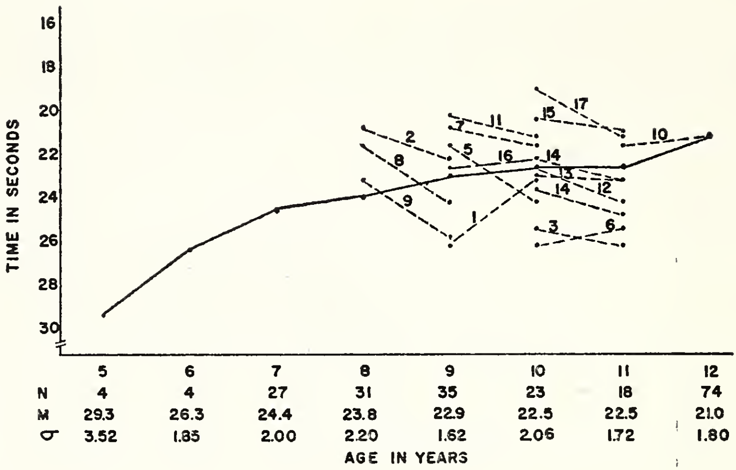


Figure 45—Agility run: comparison of pretraining and post-training test scores with age performance curves by tangents.

Strength

Landry (98) found decreases in strength / body weight in 12 of his 17 subjects over the one-year period. The difference between the group means, 4.8 pounds in the first year and 4.7 in the second, was not statistically significant. It should be noted here that the age-performance curve for this test item, and for all the static strength measures, shows a decline around the age of 11 years, which probably accounts for the losses recorded in these subjects.

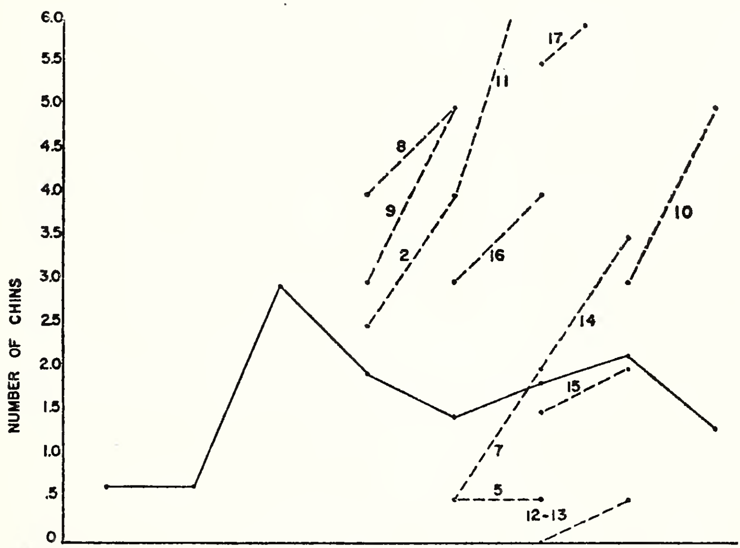
In a similar analysis of 30 subjects enrolled in two consecutive summer programs, and with the initial test scores used again for both years, Lent (107) found that 11 boys improved beyond the normal growth pattern, 13 followed the normal growth trends, and 6 showed no change in strength. The age range for these subjects was 7 to 15 years. Lent noted that the most marked improvements were shown by boys approaching puberty, and in those initially below the average for their age group.

Power

Of Landry's 17 subjects, 8 retrogressed in vertical jump ability, 3 remained the same, and 6 improved. The group mean in the first year was 10.8 inches, and in the second, 10.6 inches, representing a loss of 4 standard scores. This difference was not statistically significant.

Muscular Endurance

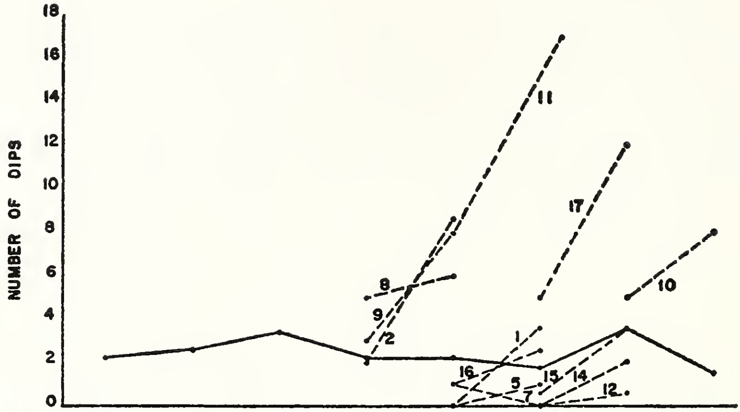
Marked improvements in the muscular endurance of the shoulders were shown by 12 of Landry's 17 subjects over one year. The group mean increase of 0.9 chins and 2.4 dips on the parallel bars was found to be significant when related to the standard errors of measurement. Time for the V-sit and the number of endurance hops (mean increases of 9 seconds and 61 hops) also improved, but the differences were not significant. The individual changes in chins, dips, and endurance hops are shown in Figures 46, 47, and 48.



AGE	5	6	7	8	9	10	11	12
N	7	4	28	37	35	26	16	18
M	.6428	.620	2.98	1.89	1.40	1.80	2.12	1.38
σ	1.09	.422	2.21	1.85	1.37	2.10	1.51	2.04

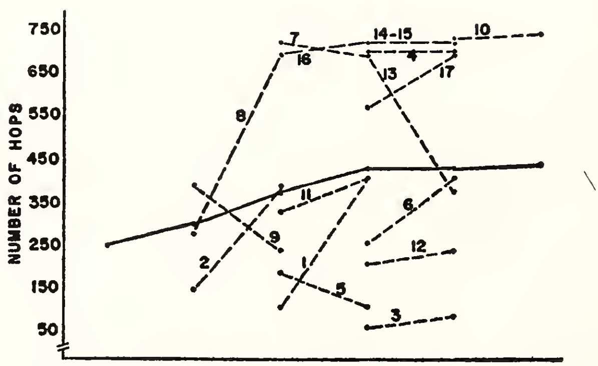
FIGURE 46—Chinning: comparison of pretraining and post-training test scores.

The assumption in the above studies is that boys who participate in the summer school for one year are motivated to continue their interest in physical activities throughout the year. Whether or not this assumption is justified is debatable, and the studies can by no means be considered crucial experiments. That there is great variability in the response patterns over the year is obvious. This is probably due to the manner in which individual boys adapt to physical activity. In summary, it can be said that the majority of the boys in the sample improved in balance, backward extension of the



AGE	5	6	7	8	9	10	11	12
N	7	4	28	36	35	26	15	19
M	.212	.250	3.41	2.25	2.114	1.94	3.63	1.657
σ	.114	.422	2.97	2.39	2.84	2.82	2.18	3.45

Figure 47—Dipping: comparison of pretraining and post-training test scores.



AGE	7	8	9	10	11	12
N	23	33	25	31	16	14
M	263.5	311.0	384.4	442.8	442.0	447.1
σ	225.5	220.0	226.7	248.4	248.1	187.9

Figure 48—Endurance hops: comparison of pretraining and post-training test scores.

trunk, and in muscular endurance of the upper arms and shoulders, while losses were sustained in agility.

Changes in Motor Fitness Associated with Combined Skill and Endurance Programs

The rather indifferent changes, especially in the area of circulatory-respiratory fitness, associated with the skill-based program led to increases in the endurance content of the training. While instruction in the four activities of gymnastics, track and field, swimming, and games was retained, an additional 30 minutes of endurance training was added. In the three studies cited in this section, the endurance training took the form of steeplechase, muscular endurance exercises, interval training or circuit training, the four matched groups being based on initial 600-yard run times. The training in each of these areas was as follows:

Steeplechase

The boys were urged to run as far and as fast as possible without stopping. The course varied from day to day, but usually included mounting stairs and traversing the various teaching areas and fields.

Muscular Endurance

A selection of muscular endurance exercises was administered each day, three of them being done "all-out." The core of exercises included floor push-ups, side leg raisings, endurance hops, leg lifts, sit-ups, squat jumps, V-sit, and Burpee 4-count exercise.

Interval Training

This consisted of speed work with the boys running short efforts at full speed, for example, on one day, five 110-yard sprints; the next, four 220 plus one 110; the following day, one 110, one 440, two 110. The number of efforts run each day depended on the individual's ability, with the number increasing as the program progressed.

Circuit Training

This was essentially a combination of interval running and muscular endurance exercises, one day's program including the following: run 220, endurance hops, run 220, floor push-ups, run 220, sit-ups, run 220, backward leg raising, run 220, side leg raising, run 220, sitting tucks. The number of repetitions of each exercise was increased each week.

The effects of this program of combined skill instruction and endurance training on agility, vertical jump, reaction time, and strength have been reported in the following studies.

Agility and Vertical-Jump Reaction Time

Tillman (153) studied 71 boys 7 to 14 years of age using four matched groups, each following one of the endurance training programs outlined above. Comparison of the pre- and post-training scores of each group with the other groups showed no statistically significant differences either in the Illinois Agility Run or Vertical-Jump Reaction Time. This negative finding is not surprising in view of what is known of the effects of stress on the nervous system. In fact, it is unlikely that post-training measurements of variables which reflect the condition of the nervous system, and which are recorded immediately at the conclusion of a training program, will show improvements over pretraining measurements when the data are subjected to group analysis, as young subjects with labile nervous systems are usually thrown into a state of mild, temporary stress, from which they recover quickly and frequently to a higher level of physiological adaptation, as shown by Barry (10).

Strength

A group analysis by Butler (19) of 68 boys engaged in a program similar to the one outlined above revealed statistically significant increases in grip strength for the muscular endurance exercise group and a significant decrease in back strength for the cross-country group. In the total group analysis, right grip strength and strength / body weight showed statistically significant improvements. The three boys showing the greatest gains were in the prepubertal growth stage, which suggests that training can act independently of maturation. A more rigorous statistical comparison of these four groups by Conner (27) led to the conclusion that, while muscular endurance exercises were superior for increasing the strength of the hands, interval training was the best method of the four for increasing over-all strength.

Changes in Motor Fitness Associated with Other Specific Training Programs

Following each summer school, the parents of each participant are interviewed. Interpretations of the various tests are given and recommendations made where necessary. The procedure is time-consuming (70 one-hour interviews), but this phase of the program seems quite essential if the physical education experience given a child is to be followed through with such persistence as the careful collection and measurement of physical fitness data merit. Usually, about 25 per cent of the participants show marked deficiencies in one or more of the motor areas (poor balance, flexibility, agility, strength, power, and endurance). Sometimes, there is a predisposing factor, such as weak feet, poor body mechanics, poor neuromuscular coordi-

nation, or problems of weight control (under- or overweight). Within the experience provided by our own sample, the four most frequently recurring problems are: structurally and/or functionally weak feet, low strength in the upper arms and shoulders, poor circulatory-respiratory endurance, and overweight.

Various experimental programs have been conducted in an effort to improve these specific deficiencies. For the most part, small, homogeneous groups of 3 to 10 boys have been used, the formal training sessions being conducted on Saturday mornings (1½ to 3 hours) and informal training at home being supervised by the parents. The length of the training has varied from 9 to 21 weeks. The changes resulting from these programs are reported here.

Rope Skipping

Powell (129) took a group of five 10-year-old boys and trained them with a skipping program for nine weeks (Figure 49). While the effects of the training on circulatory-respiratory fitness were the prime consideration, the

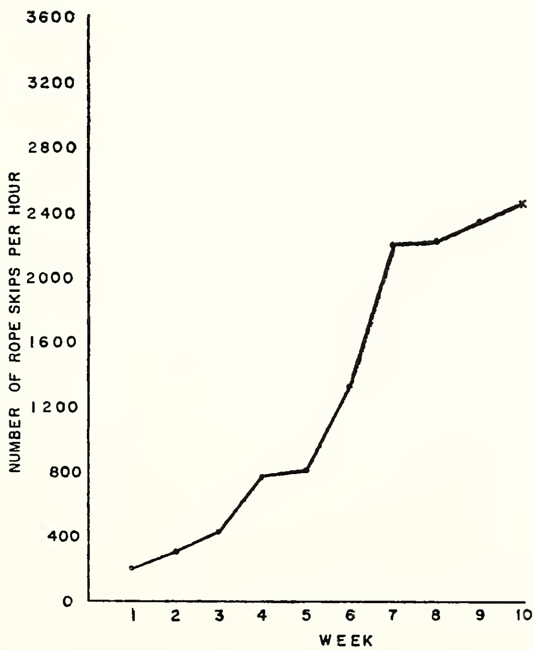


FIGURE 49—Number of rope skips per hour on 10 successive Saturdays.

changes in motor performance are worth noting. Each boy was issued a rope and was asked to skip for 15 minutes each day at home. The Saturday class was 1½ hours long; and here, in addition to the actual training, new techniques were learned and progress tested. This phase of the program is described by Powell as follows: "The first half hour was devoted to a gradual warm-up; for the first 15 minutes the writer led the class in running, walking, and through a series of exercises. These were designed to activate the body through a full range including lateral, abdominal, dorsal, balance, leg, trunk, arm, shoulder flexibility, agility, and general massive body movements. For the second half of the warm-up, new skip steps were demonstrated, taught, and practiced and the subjects were helped individually to improve their skipping technique . . . for the next hours, the subjects knew there were three personal competitions . . . (1) the greatest number of rope skips made in one hour; (2) the greatest number of rope skips made in five consecutive efforts; (3) the greatest number of rope skips made without a mistake. Thus, each participant had an incentive to beat personal best performances established from week to week" (129, pp. 24-25). Figure 49 shows the progress made by one of the five subjects in one of these weekly competitions (the number of rope skips in one hour).

The following changes in motor fitness were observed in the five subjects.

Balance. Four of the five subjects improved in the progressive balance beam test (5, 7, 17, and 20 standard scores), while the fifth scored the maximum possible both before and after training.

TABLE 9

Changes in Flexibility Associated with Two Follow-up Programs (from Pattee and Powell)

	Flexion Forward (in.)			*Extension Backward* (in.)			*Right Ankle Flexion* (°)			*Left Ankle Flexion* (°)		
	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain
Pattee's Subjects												
A	10.1	12.5	−7	8.3	15.3	+37	70.0	58.0	−16	78.0	60.0	−29
B	10.6	10.5	0	15.2	15.0	−1	68.0	73.0	+8	75.0	70.0	−7
C	15.5	10.5	+23	20.2	23.9	+18	47.0	37.5	−13	77.0	69.0	−15
Powell's Subjects												
A	6.5	6.5	0	16.5	20.0	+20	54.5	68.0	+20	53.5	67.0	+20
B	14.0	12.0	−10	12.5	11.0	−7	57.0	60.0	+4	58.5	73.5	+24
C	14.0	12.0	−10	11.0	18.0	+43	57.5	71.0	+10	58.0	60.0	+10
D	12.0	12.0	0	16.0	18.0	+10	47.5	58.0	+14	45.0	56.0	+36
E	15.0	15.0	0	12.5	13.5	+2	47.5	58.0	+14	50.0	58.0	+6

Flexibility. The changes in trunk forward flexion, trunk extension backward, and ankle flexibility are shown in Table 9. The rope skipping produced considerable improvement in ankle flexibility, while losses in trunk forward flexion were shown by two subjects. This loss is probably related to shortening of the hamstring muscles. The improvements in trunk extension backward may be partly due to strengthening of the upper back musculature, as shoulder strengthening exercises were included in the warm-up work.

TABLE 10

Changes in Agility and Reaction Time Associated with Two Follow-up Programs (from Pattee and Powell)

	Illinois Agility Run (sec.)			*Visual Reaction Time* (sec.)			*Auditory Reaction Time* (sec.)			*Combined Reaction Time* (sec.)		
	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain
Pattee's Subjects												
A	20.5	19.0	+14	.32	.32	0	.27	.29	−10	.29	.32	− 7
B	22.4	22.0	+ 3	.25	.27	−15	.25	.25	0	.25	.26	− 2
C	24.2	23.0	+11	.31	.27	+ 8	.30	.28	+10	.29	.28	+ 4
Powell's Subjects												
A	19.5	16.5	+29	.30	.28	+ 5	.34	.28	+12	.39	.29	+21
B	19.5	18.5	+10	.28	.22	+14	.26	.22	+14	.26	.22	+ 9
C	19.0	17.0	+19	.33	.24	+20	.25	.20	+10	.28	.20	+16
D	19.5	18.0	+15	.35	.32	+ 6	.25	.20	+15	.36	.24	+28
E	28.0	24.5	+32	.40	.37	+ 5	.40	.36	+ 8	.37	.35	+ 5

Agility and vertical-jump reaction time. Table 10 shows the changes in the Illinois Agility Run, visual, auditory, and combined visual-auditory reaction times. Standard score gains around the order of 10 to 15 standard scores were made by all subjects in all these tests.

Strength. Static strength changes in four tests (right and left grip, back lift, and leg strength), together with total strength and strength / body weight, are shown in Table 11. In general, large gains were made in leg strength and back lift, but the rope-skipping had little effect on the grip strengths.

Power. Substantial standard score gains were made by four of the five subjects in 60-yard dash time, by all subjects in vertical jump, and by four subjects in the standing broad jump (Table 12).

Muscular endurance. Marked improvements occurred in four subjects in chinning, in three in dips on the parallel bars, while all five subjects im-

Table 11

Changes in Strength Associated with Two Follow-up Programs
(from Pattee and Powell)

	Right Grip Strength (lb.)			*Left Grip Strength* (lb.)			*Back Lift* (lb.)			*Leg Lift* (lb.)			*Total Strength* (lb.)			*Strength/ Weight*		
	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain
Pattee's Subjects																		
Subject A	20.0	30.0	+16	19.0	28.0	+13	50.0	52.0	+ 1	30.0	50.0	+ 4	119.0	160.0	+ 8	1.63	2.06	+ 6
Subject B	40.0	42.0	+ 3	37.0	35.0	− 3	108.0	130.0	+12	137.0	85.0	−18	322.0	292.0	− 4	3.39	2.89	− 6
Subject C	40.0	40.0	0	32.0	44.0	+17	200.0	140.0	−30	270.0	165.0	−37	542.0	389.0	−27	4.48	3.09	−17
Powell's Subjects																		
Subject A	52.0	52.0	0	40.0	42.0	+ 3	200.0	240.0	+20	200.0	270.0	+14	492.0	604.0	+18	5.32	6.64	+19
Subject B	32.0	28.0	− 5	22.0	30.0	+11	120.0	140.0	+10	170.0	170.0	0	344.0	368.0	+ 4	4.05	4.18	+ 2
Subject C	34.0	34.0	0	30.0	30.0	0	180.0	200.0	+ 8	220.0	260.0	+ 5	464.0	524.0	+10	6.11	6.47	+ 5
Subject D	48.0	42.0	− 8	34.0	34.0	0	190.0	240.0	+26	195.0	250.0	+12	467.0	566.0	+15	4.92	5.60	+ 8
Subject E	44.0	45.0	+ 1	36.0	44.0	+ 9	145.0	223.0	+40	150.0	390.0	+60	375.0	700.0	+52	2.85	5.85	+33

TABLE 12

Changes in Power Associated with Two Follow-up Programs
(from Pattee and Powell)

	Sixty-Yard Dash (sec.)			*Vertical Jump* (in.)			*Standing Broad Jump* (in.)		
	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain
Pattee's Subjects									
A	10.6	10.3	+ 6	10.5	12.0	+13	62.0	59.0	− 3
B	10.6	10.3	+ 6	11.5	12.0	+ 3	66.0	64.0	− 2
C	11.1	10.5	+11	7.5	10.5	+25	45.0	58.0	+11
Powell's Subjects									
A	11.0	9.8	+22	11.0	15.0	+18	68.0	71.0	+ 5
B	12.0	11.2	+20	7.5	11.5	+20	60.0	60.0	0
C	12.0	10.8	+31	10.0	14.5	+20	58.0	60.0	+ 5
D	11.8	12.8	−18	7.5	10.5	+14	45.0	56.0	+27
E	14.8	13.5	+22	7.0	10.5	+17	50.0	58.0	+14

proved in endurance hopping (Table 13). The rope-skipping program had little effect on the muscular endurance of the abdomen.

Running and Calisthenics

Pattee (125) exposed three subjects to a 13-week program of running and calisthenics, formal training being conducted over 13 Saturday mornings for two hours. The first hour was spent running indoors (10 minutes of alternate laps of running and walking). Progression was achieved by increasing the speed of running. Following this, each boy did as many floor push-ups, sit-ups, and squat jumps as possible in one minute, with each subject competing against his score of the previous week. The remaining 30 minutes were spent in calisthenics, medicine ball work, pulley weights, rowing, rope climbing, and horizontal bar exercises. Each boy was provided with a skipping rope and was asked to skip for 15 minutes each day and to perform as well three of the muscular endurance items. This mixed running and calisthenics program brought the following changes.

Balance. All three of Pattee's subjects recorded poorer scores on the progressive balance beam test, losing 2, 10, and 20 standard scores. This points to the specificity of these components of motor fitness and shows that running combined with rhythmical endurance exercises is not the same as gymnastic training for balance.

Flexibility. Losses in ankle flexibility were pronounced (Table 9), whereas two of the subjects improved in trunk extension backward. The latter change is probably associated with strengthening of the upper back musculature.

TABLE 13

Changes in Muscular Endurance Associated with Two Follow-up Programs (from Pattee and Powell)

	V-Sit (sec.)			*Chins* (no.)			*Dips* (no.)			*Endurance Hops* (no.)		
	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain	T_1	T_2	S.S. Gain
Pattee's Subjects												
A	9	30	+20	0	1.0	+15	1.5	1.5	0	710	742	+29
B	17	28	+12	.5	1.0	+ 5	.5	.5	0	300	200	− 6
C	6	9	+ 3	0	.5	+10	.5	.5	0	230	700	+33
Powell's Subjects												
A	60	60	0	0	1.5	+50	.5	.5	0	727	736	+ 9
B	10	12	+ 2	0	.5	+30	0	1.0	+45	508	734	+47
C	60	60	0	1.0	3.0	+20	.5	1.5	+15	727	736	+ 9
D	50	23	−19	1.0	1.5	+ 5	.5	.5	0	727	733	+ 5
E	5	15	+ 9	0	0	0	0	.5	+35	470	704	+15

Agility and vertical-jump reaction time. All three subjects improved in the Illinois Agility Run, but the changes in vertical-jump reaction time were small and both positive and negative (Table 10). The changes in this area are by no means as large and consistent as was the case with the rope-skippers.

Strength. Table 11 shows the changes in four static strength tests, as well as total strength and strength / body weight. The changes are inconsistent, and again considerably less than was the case in the rope-skipping study.

Power. All three of Pattee's subjects improved in 60-yard dash time and vertical jump, while two made small losses in standing broad jump (Table 12).

Muscular endurance. The emphasis on muscular endurance in this program may be gauged from the changes in V-sit, chins, and endurance hops (Table 13), where, with one exception, consistent improvements were shown. That the arm extensor muscles received less attention than the arm flexors is reflected in the comparative changes shown in chinning and dips.

Endurance Running and Calisthenics

Knowlton (89) matched four experimental subjects and four control subjects (all 7 to 9 years of age) on the Cureton five-item muscular endurance test (floor push-ups, chins, backward leg raisings, lateral leg raisings, and mile run). He then exposed the experimental subjects to a 13-week program of endurance running and muscular endurance exercises, while the controls were given instruction in skill activities and games in a manner simulating a typical elementary school physical education program. The endurance running for the experimental subjects was varied from week to week with regard to distance and pace (one 1-mile, two ½-mile, etc.), and this was done after a selection of "all-out" muscular endurance exercises, usually four or five each Saturday from the following list: floor push-ups, sit-ups, deep knee bends, lateral leg raisings, backward leg raisings, rope climbing, endurance hops, treadmill running. The training each Saturday lasted three hours, culminating with a short play period, in which the experimental and control subjects joined. The experimental subjects were encouraged by means of check lists to continue their training at home during the week.

The experimental group in this study made highly significant improvements in floor push-ups (mean increase of 6.2 push-ups), backward leg raisings (+107) and mile run (−45.5 seconds). The changes in lateral leg raisings and chins were not statistically significant. No significant changes were made by the control group in any of the five endurance items.

Mixed Shoulder-Strengthening Activities

Stableford (146) selected five boys (8, 9, and 10 years old) who had weak upper arms and shoulders and exposed them to a 14-week program of progressive resistance exercises. The initial strength status of the five subjects (and one control subject) was measured using chinning, medicine ball put for distance and height, a pulley weight exercise at a selected cadence, floor push-ups from a kneeling position, and rope climb for height. Home training was supervised by the parents, and dosage was progressively increased in a small group of exercises requiring little apparatus (pull-ups, push-ups, chinning). Check lists were used to record the progress in this home training.

The two-hour Saturday program consisted of warm-up calisthenics, followed by seven basic exercises—chinning, ladder work, medicine ball activities, pulley weight exercises, push-ups, rope climbing, and rowing on stationary apparatus. The dosage was progressively increased in each. Other activities engaged in intermittently were 600-yard run, obstacle races, relay games, tag games, basketball, softball, and cross-country running.

Table 14 shows the changes by group means in each of the test exercises. The control subject made no changes that could be attributed to anything other than chance, whereas the experimental subjects made statistically significant changes in 9 of 30 tests (range of 0 to 3 for each subject).

TABLE 14

Comparison by Means of Pre- and Post-Training Upper-Body Strength Tests with Standard Error of Difference between Means (Stableford, 1958)

			DIFFERENCES		
Test	*Mean T_1*	*Mean T_2*	*Means*	*Stand. Scs.*	*$SE_{diff.}$*
Medicine-ball-put —height (in.)	38.2 (48.3)	44.0 (51.0)	+ 5.8 (2.8)	+16 (+8)	6.3
Medicine-ball-put —distance (in.)	129.4 (158.0)	152.0 (167.0)	+22.6 (9.0)	+14 (+4)	16.4
Rope climb (in.)	66.0 (186.0)	86.4 (193.0)	+20.4 (7.0)	+ 5 (+2)	14.5
Push-ups—knees (no.)	26.0 (28.0)	63.0 (33.0)	+37.0 (5.0)	+12 (+3)	14.2
Chinning (no.)	0.1 (4.0)	1.1 (4.0)	+ 1.0 (0.0)	+10 (0)	0.3
Pulley weights (min., sec.)	1, 31 (1, 53)	3, 31 (2, 37)	+2, 00 (0, 44)	+21 (+7)	1, 01

NOTE.—Scores of control subject in parentheses. All six differences between means were nonsignificant; the last three showed a trend toward improvement.

These individual changes are not observable in the table, where the group changes for knee push-ups, chinning, and the pulley weights exercise approach statistical significance.

Medicine Ball Training

Araki (4) measured the changes in upper body strength resulting from a 21-week program of medicine ball activities. The six subjects (7 to 12 years of age) were lent medicine balls and completed 30 minutes per day of throwing under parental supervision. The two hours of training each Saturday were devoted to three sets of 15 basic exercises (1½ hours) plus ½ hour of medicine ball games. The basic exercises comprised 15 different types of throwing to a partner, two minutes per type, with the number of throws per minute increasing from 15 in the first week to 55 in the 21st week. The dosage of the training at home was controlled in a similar manner. Three control subjects were used in the study, one of whom participated in no training at all, another in the Saturday work only, and another in 10 weeks, or half, of the full training program. The statistical significance of the individual pre- and post-training scores was computed for 20 motor tests; and the results, in terms of the number of experimental and control subjects showing statistically significant increases in each test, are shown in Table 15. Conspicuous improvements were shown in hang-stretch, floor push-ups, grip strength, back strength, and pull strength; but it should be noted that these changes were not sufficient to enable the subjects to handle the total body weight in chinning and dips.

TABLE 15

Frequency of Occurrence of Statistically Significant Changes in Strength Tests for Six Experimental and Three Control Subjects (Araki, 1960)

Test	Number of Subjects Showing Statistically Significant Changes *Experimental* ($N=6$)	*Control* ($N=3$)
Chinning (no.)	0	0
Dips (no.)	1	0
V-sit (sec.)	0	0
Hang-stretch (sec.)	5	0
Floor push-ups (no.)	4	2 (Sat. only, 10 weeks)
Grip strength—right (lb.)	6	0
Grip strength—left (lb.)	5	2 (no training, 10 weeks)
Back strength (lb.)	5	0
Leg lift (lb.)	0	0
Pull strength (lb.)	6	0
Total strength (lb.)	3	0
Strength / body weight	1	0
Trunk forward flexion (in.)	1	0
Trunk backward extension (in.)	0	0
Vital capacity residual (cc.)	0	0
Squat stand (sec.)	2	0
Medicine-ball-put—1 hand (in.)	1	0
Medicine-ball-put—2 hands (in.)	2	1 (Sat. only)
Neck bridge (sec.)	0	0
Rope climb—height (in.)	2	0

Weight Training

Weight training is not normally used in schools, primarily because of the cost of the equipment and of the difficulties involved in its administration and supervision. There is mounting evidence, however, that weight training, adequately supervised as a form of progressive resistance exercise, provides an efficient means for developing the strength of specific muscle groups (22, 26, 85) and, further, that certain minimal levels of strength in specific muscle groups are essential to the performance of certain dynamic strength movements such as chinning (15).

Taking a group of six young boys (7 to 12 years of age) who had been found deficient in upper body development and three control subjects, Larson (100) used as a training modality a 10-week progressive resistance exercise program with two one-hour sessions during the week and a two-

hour session on Saturday mornings. The training consisted of five exercises: two-arm curl, bench press, upright rowing, lateral raise, and bent-over rowing, which were preceded by ten minutes of warm-up calisthenics. The subject's starting weight in each exercise was determined by the weight he could handle for eight repetitions without stopping. Each subject attempted to increase the number of repetitions of each exercise in a set from eight to twelve. When the number of repetitions of a particular exercise had increased to twelve, the weight was increased by the addition of plates to the barbells so that a maximum of eight repetitions could be attained. Two sets of each exercise were completed at each session.

TABLE 16

Pre- and Post-Training Changes in Standard-Score Means Associated with Ten Weeks of Weight Training ($N = 6$) (Larson†)

	STANDARD SCORES				
Test	*Mean* T_1	*Mean* T_2	*Difference*	$SE_{diff.}$	t
Right-hand grip	56.8	62.0	+ 5.2	3.371	1.534
Left-hand grip	64.5	69.5	+ 5.0	2.634	1.898
Back strength	37.0	47.7	+10.7	4.639	2.299
Leg strength	35.7	42.8	+ 7.1	2.445	2.921*
Total strength	40.7	49.7	+ 9.0	2.557	3.520*
Strength / body weight	41.7	49.8	+ 8.1	2.252	3.628*
Elbow flexion strength	42.0	59.0	+17.0	2.944	5.774**
Elbow extension strength	38.0	45.3	+ 7.3	2.226	3.293*
Shoulder flexion strength	29.3	63.8	+34.5	8.445	4.085**
Shoulder extension strength	42.8	61.5	+18.7	2.397	7.789**
Chins	15.8	42.8	+27.0	2.532	1.883
Dips	7.5	52.5	+45.0	8.853	5.083**
Floor push-ups	30.5	48.0	+17.5	4.185	4.182**

* Significant at .05 level of confidence.
** Significant at .01 level of confidence.
† Charles E. Larson, M.S. thesis, College of Physical Education, University of Illinois, 1961.

The effects of the weight training were evaluated in terms of dynamometric strength tests (left and right grips, back and leg lift), cable tension strength tests (elbow flexion and extension, shoulder flexion and extension), and dynamic strength tests (chins, dips, and floor push-ups). As a group, the experimental subjects made statistically significant gains in all the tests except left and right grips, back strength, and chinning (Table 16), whereas the control subjects showed nonsignificant changes. In general, a decrease

in the test scores was observed in the first two or three weeks, and marked fluctuations in performance were noted from week to week. A comparison of the changes in this study with those associated with mixed developmental activities (Stableford [146]) and medicine ball work (Araki [4]) appear to favor the weight training as a means of developing the strength of the arms and shoulder girdle.

Longitudinal Records of Ten Boys in Program over Three or More Years

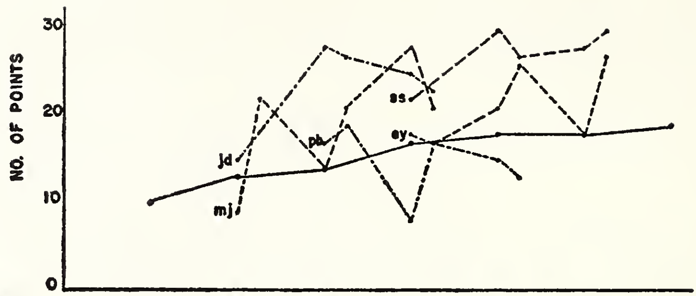
The progressive changes, both pre- to post-training and from year to year, are shown for several subjects in Figures 50 to 62. In general, the subjects show a better adaptation to the summer training after the first year of participation in the summer school, and usually, though not invariably, improvements over the summer contrasted to retrogression throughout the remainder of the year. The changes may be summarized thus:

Balance. No systematic group pattern emerges (Figure 50). In most, but not all, cases improvements in balance are in evidence. The positive and negative fluctuations throughout the year probably reflect specific activities engaged in by the individuals.

Flexibility. In both tests, trunk flexion forward and extension backward, there is a trend toward improvement during the summer and loss of flexibility throughout the rest of the year, this trend being more marked in the case of extension backward. Insufficient evidence is available on the influence of seasonal variations on these flexibility measurements to be able to attribute the changes to the summer training alone, although the changes in the slope of the curves, when viewed alongside the normal age-performance curve, are suggestive that the increased activity over the summer is associated with improved flexibility (Figures 51 and 52).

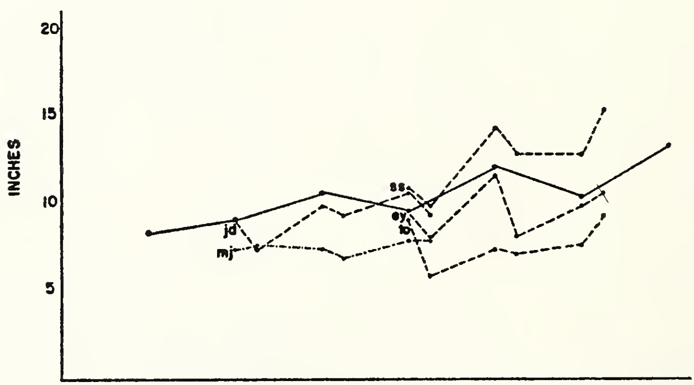
Power. Figures 53 to 58 show the changes in various power items (60-yard dash, vertical jump, standing and running broad jumps, running high jump, and 8-pound shot-put) in subjects who attended the summer school for three consecutive years. In some cases, the post-training measurements appear to be affected by transient fatigue, and this seems more prevalent in the 9- to 11-year age group. The curves illustrate well the great intra-individual variation throughout the year, and in consecutive years, the results of the combined forces of seasonal variations, nutrition, training (or nontraining), and maturation influences.

Muscular endurance. Intra-individual differences in the development of muscular endurance may be observed for chinning, dips, 600-yard run, and endurance hops in Figures 59 to 62. The individual curves, covering three summer training sessions and two intermediate years, illustrate well the perversity of motor development in young boys.



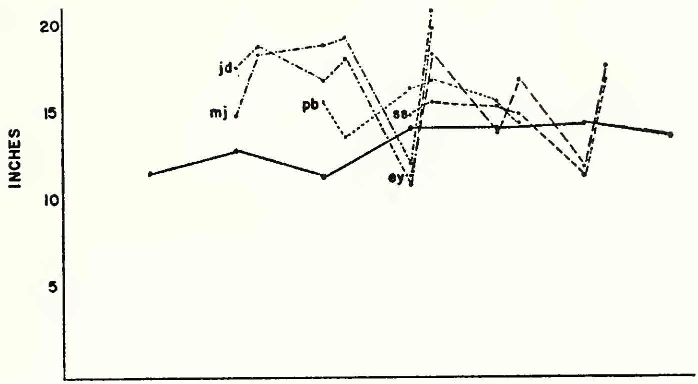
AGE (YRS.)	7	8	9	10	11	12	13
MEAN	10	13	14	17	18	18	19
NUMBER	53	70	58	59	41	12	8
σ	5.7	7.0	5.5	6.6	5.7	6.2	7.9

Figure 50—Balance beam: pre- to post-training and yearly changes related to age performance curve.



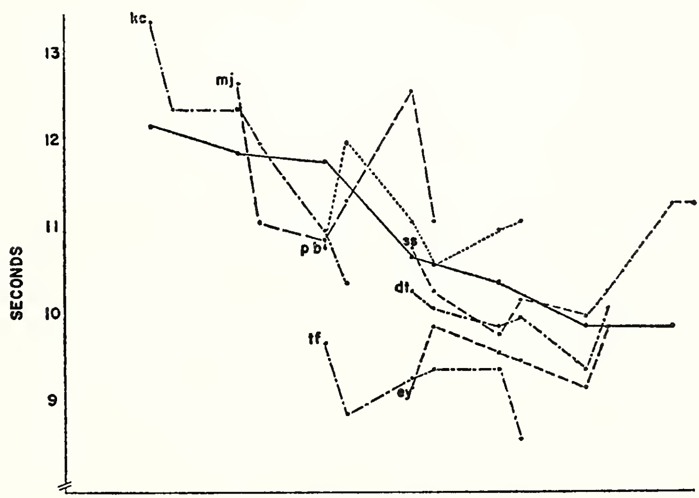
AGE (YRS.)	7	8	9	10	11	12	13
MEAN (INCHES)	8.5	9.4	10.8	9.8	11.1	10.5	12.5
NUMBER	60	69	56	49	37	19	11
σ	2.22	3.03	2.58	2.92	2.85	2.21	2.27

Figure 51—Trunk forward flexion: pre- to post-training and yearly changes related to age performance curve.



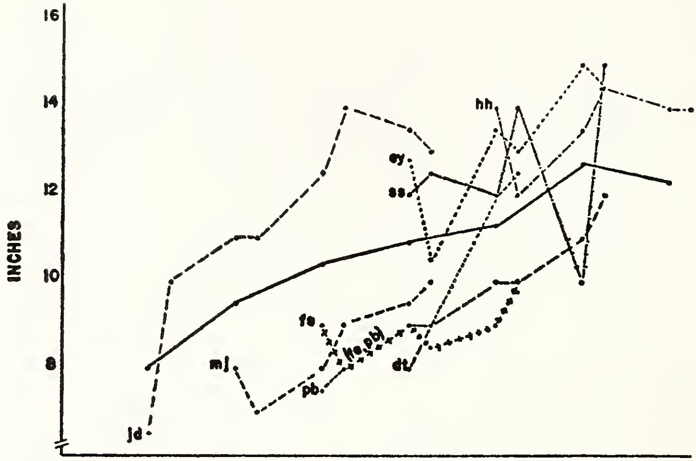
AGE (YRS.)	7	8	9	10	11	12	13
MEAN	11.7	12.7	11.6	14.1	14.1	14.3	13.6
NUMBER	65	71	65	53	39	23	13
σ	3.13	3.65	3.35	3.31	3.66	3.28	3.39

Figure 52—Trunk backward extension: pre- to post-training and yearly changes related to age performance curve.



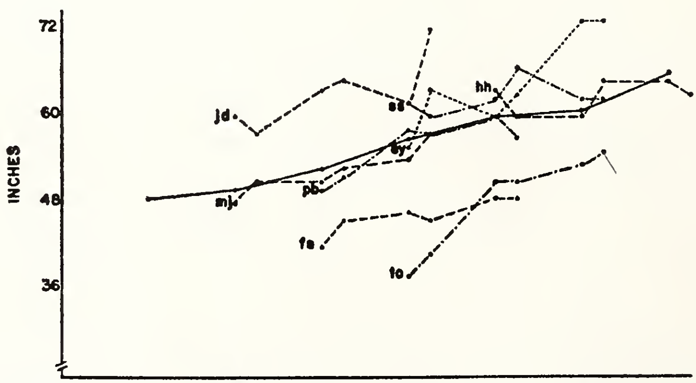
AGE	7	8	9	10	11	12	13
MEAN (SECONDS)	12.2	11.9	10.8	10.7	10.4	9.9	9.9
NUMBER	31	55	50	42	46	15	10
σ	1.19	1.37	1.08	.62	.95	1.32	.49

Figure 53—Sixty-yard run: pre- to post-training and yearly changes related to age performance curve.



AGE	7	8	9	10	11	12	13
MEAN (INCHES)	8	9.5	10.4	10.9	11.3	12.7	12.3
NUMBER	27	57	55	50	12	12	8
σ	.15	2.09	1.43	1.58	1.80	2.11	1.58

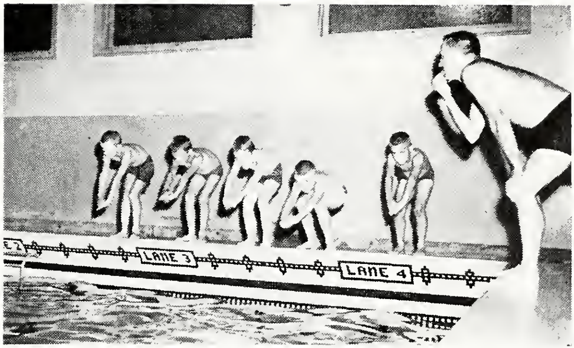
FIGURE 54—Vertical jump: pre- to post-training and yearly changes related to age performance curve.



AGE	7	8	9	10	11	12	13
MEAN (INCHES)	49	50	53	57	60	61	66
NUMBER	61	75	59	54	39	12	6
σ	6.7	7.2	3.7	7.8	6.8	10.9	6.9

FIGURE 55—Standing broad jump: pre- to post-training and yearly changes related to age performance curve.

(a) Learning to plunge.



(b) Strengthening the arms and shoulders with weight-training: here, bench pressing.

(c) Strengthening the abdominal muscles in the gymnastics program.

PLATE VII—Sports-Fitness School: activities.

(a) Learning the skills of archery in the sports and games program.

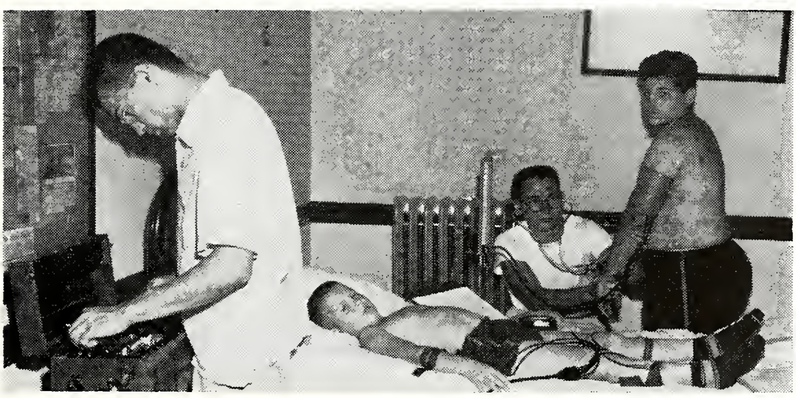
(b) Relay racing in the track and field program.

(c) Soccer, a part of the sports and games program.

PLATE VIII—Sports-Fitness School: activities.

(a) Reaction time test of total body speed in response to light and sound signals.

(b) Dynamometer back lift.



(c) Direct body ballistocardiograph.

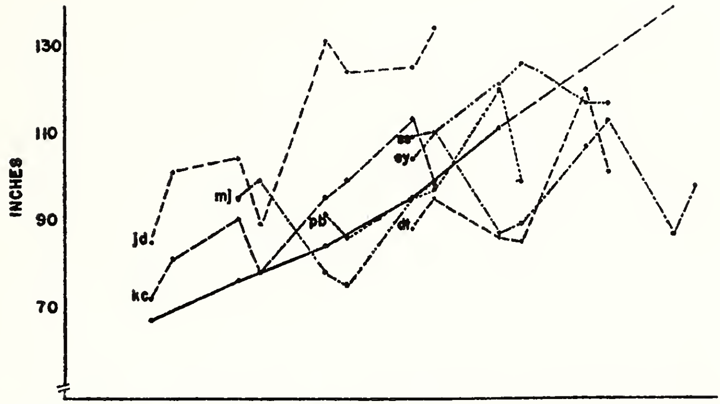
PLATE IX— Physical Fitness Laboratory: testing procedures.

(a) Skin-through and reverse.

(b) Learning to use exercise equipment individually.

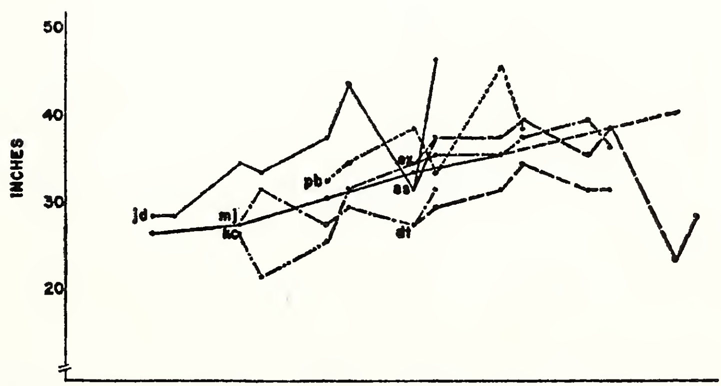
(c) Heel to toe push-up.

Plate X—Sports-Fitness School: gymnastics, exercise equipment, and posture work.



AGE	7	8	9	10	11	12	13
MEAN (INCHES)	68	77	85	96	102		
NUMBER	34	45	58	42	39		
σ	15.7	19.4	14.7	15.2	20.3		

Figure 56—Running broad jump: pre- to post-training and yearly changes related to age performance curve.



AGE (YRS)	7	8	9	10	11	12	13
MEAN (INCHES)	27	28	31	34	38		
NUMBER	30	62	57	44	44		
σ	4.0	1.2	1.8	3.3	5.4		

Figure 57—Running high jump: pre- to post-training and yearly changes related to age performance curve.

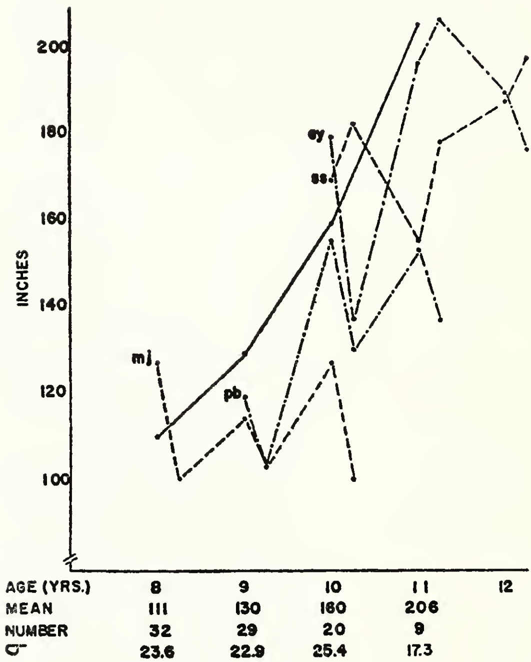
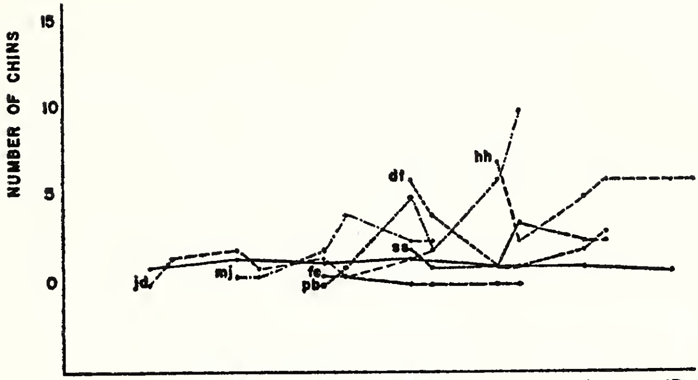
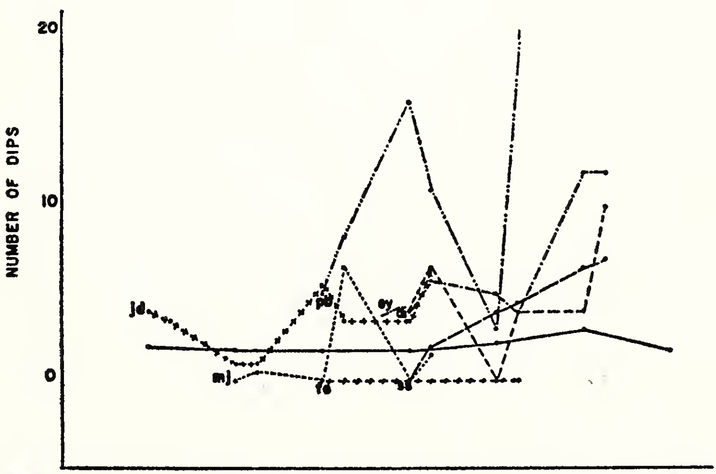


Figure 58—Eight-pound shot-put: pre- to post-training and yearly changes related to age performance curve.



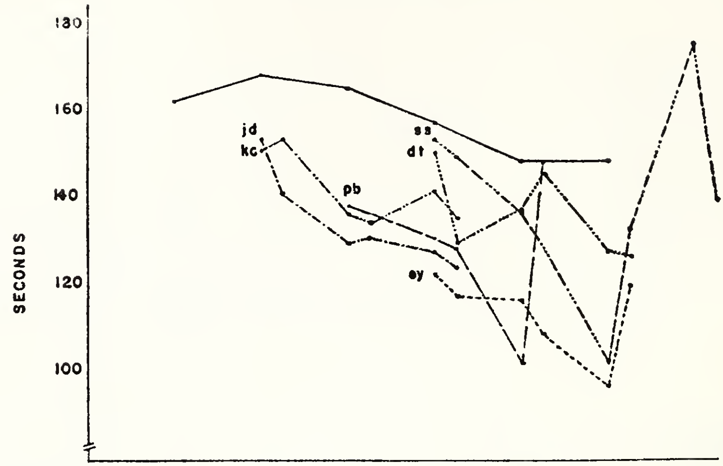
AGE	7	8	9	10	11	12	13
MEAN	1.0	1.5	1.2	1.5	1.1	1.1	.8
NUMBER	24	55	53	53	11	12	7
σ	1.18	.39	1.65	.43	1.29	1.34	.87

Figure 59—Chins: pre- to post-training and yearly changes related to age performance curve.



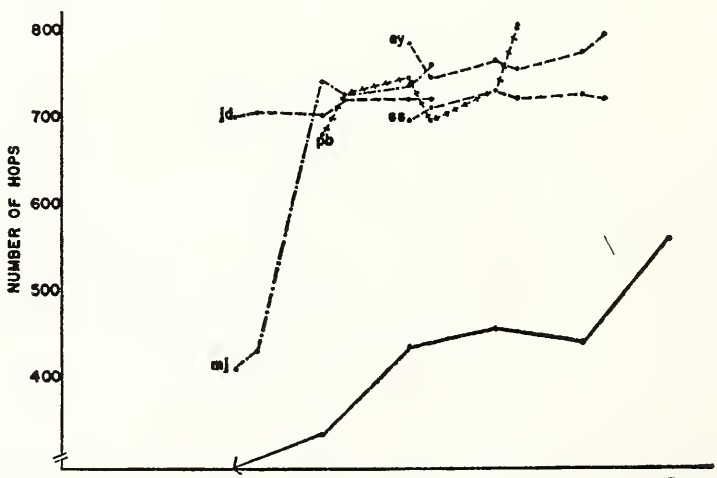
AGE (YRS.)	7	8	9	10	11	12	13
MEAN	1.9	1.8	1.8	1.8	2.1	2.8	1.6
NUMBER	26	57	54	53	12	12	8
σ	1.87	1.91	2.13	2.37	2.54	2.25	1.30

Figure 60—Dips: pre- to post-training and yearly changes related to age performance curve.



AGE (YRS.)	7	8	9	10	11	12	13
MEAN (SEC.)	163	169	166	158	149	149	
NUMBER	17	43	41	29	31	16	
σ	17.8	24.9	23.8	21.4	23.0	22.7	

Figure 61—600-yard run: pre- to post-training and yearly changes related to age performance curve.



AGE (YRS.)	7	8	9	10	11	12	13
MEAN	297	304	343	440	460	449	567
NUMBER	59	71	51	59	33	25	8
σ	207.4	212.1	206.5	229.9	180.9	216.6	210.9

Figure 62—Endurance hops: pre- to post-training and yearly changes related to age performance curve.

VI

THE MEANING OF CARDIOVASCULAR FITNESS IN YOUTH AND BASIC PRINCIPLES FOR ITS IMPROVEMENT BY SPORTS FITNESS PROGRAMS

Not so many years ago the attitudes of parents, physical education teachers, and a good many doctors were discouraging towards youngsters working in endurance events in physical education and athletics. Perhaps this is why the syllabi related to the elementary school include almost no progression (overload) in events which would lead to improved circulatory-respiratory endurance. The inclusion of the 600-yard run in the AAHPE&R testing program, and its previous use in the Illinois 4-H Clubs and in the Sports-Fitness School at the University of Illinois, has been accompanied by various types of studies which show us something of the conditions under which we can improve endurance and circulatory-respiratory fitness. For several years we have constantly studied the nature of the cardiovascular and respiratory changes involved with various activity programs conducted over several weeks, months, and even years, both in experimental groups and in individuals. These studies involve the use of various kinds of laboratory tests: oxygen intake (aerobic), rate of oxygen debt (anaerobic), post-exercise blood pressure, ECG's, heartographs, ballistocardiograms, step test scores, running endurance performances, and drop-off indices based on such performances. Various papers and books have been published which explain these tests (31, 34, 35, 36, 38, 45).

Tests of Circulatory-Respiratory Fitness

A condensed summary and guide to the various tests of circulatory-respiratory fitness is given in Table 17 to show the grouping of the tests according to functional components (40).

The tests as given in Table 17 have been used in this study. The most practical test in the quiet state is the heartograph (brachial pulse wave) as taken on the Cameron Heartometer and using Cureton's quantitation methods. Various validity studies and factor analysis solutions show that the brachial pulse wave and/or ballistocardiogram give the most meaningful predictions of functional endurance. These tests are also better in consistency (retest reliability) and for prediction of endurance criteria performances

TABLE 17

Guide to Tests of Circulatory-Respiratory Fitness

Relatively Good Condition	*Relatively Poor Condition*
Component I—Autonomic Nervous Balance in the Quiet State	
High Schneider index	Low Schneider index
Low Barach index	High Barach index
Low pulse rates	High pulse rates
Large amplitude and area of brachial pulse wave	Small amplitude and area of brachial pulse wave
Normal basal metabolic rate	Low basal metabolic rate
High flicker fusion frequency vision	Low flicker fusion frequency vision
Large IJ wave of ballistocardiogram	Small IJ wave of ballistocardiogram
Component II—Circulatory Adjustment, Lying or Sitting to Standing, i.e., Adjustment to Hydrostatic Pressure	
Small change in pulse rate, lying to standing	Large change in pulse rate, lying to standing
Small change in pulse pressure, lying to standing	Large change in pulse pressure, lying to standing
High score on Crampton blood ptosis test	Low score on Crampton blood ptosis test
No change, or small positive change, sitting to standing, in brachial pulse wave	Negative decrement, sitting to standing, in brachial pulse wave
Component III—Circulatory Adjustment to Moderate, Submaximal Exercise	
Low 2-min. pulse count after each of five 1-min. step tests, at 12, 18, 24, 30, and 36 steps per minute	High 2-min. pulse count after each of five 1-min. step tests, at 12, 18, 24, 30, and 36 steps per minute
Low pulse ratio after five progressive step tests, 1 min. each	High pulse ratio after five progressive step tests
Component IV—Good Neuromuscular and Circulatory Adjustment to Hard Work on the Treadmill or Step-Test Bench	
Good time on all-out treadmill run, 7 mi/hr, 8.6% grade	Poor time on all-out treadmill run, 7 mi/hr, 8.6% grade
High gross oxygen uptake during all-out treadmill run	Low gross oxygen uptake during all-out treadmill run
Low rate of oxygen debt in all-out treadmill run (or on 17-in., 30/min. step test on bench)	High rate of oxygen debt in all-out treadmill run (or on 5-min., 17-in., 30/min. bench step test)
Lower than normal diastolic blood pressure after all-out test performance	Higher than normal diastolic blood pressure after all-out test performance
Component V—Recuperation from a Hard Test Exercise	
Low pulse count in manner of Harvard (Johnson-Brouha) step test taken after hard exercise	High pulse count in manner of Harvard (Johnson-Brouha) step test taken after hard exercise

than the electrocardiograph, although the *R*- and *T*-wave precordial leads of the ECG depress in the face of fatigue and nutritional deficiencies, thus serving as a warning of unfitness, but are not as good for predicting endurance.

Pulse rates are not to be depended upon to indicate the quality of performance, especially in hard work, but are useful in mild work. The pulse rates taken in the quiet state are of very low validity in predicting the performance, as are the pulse rates taken after the exertion is over. The amount of sympathetic acceleration of pulse rate during the exertion is of some value, as are the oxygen intake and rate of oxygen debt tests.

Basic Principles of Developing Cardiovascular Fitness

Cardiovascular ("heart and blood vessels") tests tell us how easily or efficiently one does an exercise from the standpoint of energy (or oxygen) cost and, sometimes, the amount of circulation needed to perform an exercise. It is certain that, with an efficiently performing heart and a readily responsive circulation, both adequate to meet the needs, one may do a long enduring exercise of moderate intensity with relative ease, recover quickly, and even go on to a second or third hard exertion with obvious stamina. More technically, this ability to adjust quickly to exertion without undue breathlessness or feelings of internal distress, fatigue, or pain, is called "circulatory-respiratory reserve." All of this holds true if the person is muscularly adequate for the task. If, however, the muscles are inadequate or the person very heavy, the muscles may fatigue and ache.

Every parent would like to know that his or her son has a normally reacting heart and circulation, not damaged or retarded in action by childhood diseases such as rheumatic fever, influenza, scarlet fever, or measles, and is adequately conditioned for strenuous performances. It is also satisfying to know that after persistent training the circulatory-respiratory mechanisms respond and recover normally, time and again, even after hard athletic effort. It is even more satisfying to observe the improvement in these functions which usually results from physical training of the *endurance* type. When such improvements occur on acceptable standardized tests, there is positive assurance that normal adjustment occurs. Such adjustment readily occurs in young boys if the "staircase" pattern of overload is gradually applied. This means that a steady *progression of work* is alternated with proper rest, food, and sleep.

The program of "workouts" must get progressively longer and harder if improvements are made over and beyond initial adjustments. It has long been known that, when the exercises are too mild, or are confined to skills and intermittent activity in games (start-stop activity), the improvements are less—in fact, virtually negligible—than in such continuous activities as

endurance running, swimming, rowing, cycling, skating, skiing, and all such continuously performed exercises. In recent years it has been shown that the process of "interval training" is very effective in bringing about the needed mental and physiological adjustments essential for improvement. This principle, so widely used in the racing sports, can actually be applied to any person, even youngsters in the 7- to 14-year age span. In fact, if it is not applied, the *stamina* usually does not develop to the extent needed for high level endurance in athletics. Cross-country running, road work, steeple-chase, and obstacle-course work are considered excellent for training endurance.

It is important to realize that such training may, and should, start early. There is no evidence that a graduated progressive training program hurts any boy, in spite of rumors to the contrary. This concept is one of the "mistakes" in early medical and child development thinking, based upon certain fallacious observations such as, "the heart grows and develops less slowly than the body, especially does the aorta lag in keeping pace with the bodily development." This fallacy was exploded by Karpovich (84). There is no scientific support for endurance exertion causing any type of heart disease (60, 78). Normal hearts may be large or small; it is the "training" of these hearts that is important. Progressive endurance training develops more capillaries in the heart, motor brain, and muscles; and the peripheral resistance (tension) against which the heart works is reduced by developing more capillaries. This is just what endurance training does to make the circulation more adequate. The trained athlete, young or old, can open up more capillaries and do so more quickly than the normal person who is "untrained." There is also evidence now to support the concept that hard training in youth develops athletic endurance earlier; and once developed and temporarily disused it can be "trained" more quickly and to a higher level.

The trends of modern civilization are against the natural development of human stamina in the circulatory-respiratory sense. Heart disease (coronary and aortic insufficiency) has increased more than any other disease affecting adults. The same basic causes are probably related to mental disease. The first effects of the age of automation are upon us. Sedentary living, hot houses, overeating, and "soft living" are generally to blame. A host of degenerative diseases and chronic ills appears parallel with inadequate circulation and respiration.

How Early Should Endurance Training Begin?

It is our firm conviction, after more than 20 years of direct laboratory experimentation and a much longer background of practical experience, that the lack of early stamina training has been the principal defect in the

American system of physical training. Australian coaches point to "age group competition" and the longer span of training background as the principal factors that have advanced their endurance records in recent years. The play program, mainly games, and the soft "mind-bodiness" of the parents themselves, preoccupied with sedentary-social pleasures, has nearly destroyed the "toughness" that characterized the early pioneers of this country.

It is possible now to educate youth to the basic principles of circulatory-respiratory adequacy and associated stamina. The proposal is to bring youth up with more endurance training, more circulatory-respiratory tests, and more adequate nutrition, as well as education in "interval training," a progressive program of rhythmic endurance exercises (86, 87), "test-exercises" (49), and various other stamina building routines. The parents need to see the improvements that are possible with such a program. It is a neglected area in the present generation. Very seldom do even physical education teachers view sports or physical activities in the light of their effects upon cardiovascular fitness. More education in this area is greatly needed.

Precautions

Before starting any strenuous program of physical conditioning we advocate regular medical checks upon the youth, better supervision of dietary and sleep habits, and a limitation of sedentary pleasures (late nights, parties, rich food, etc.). As a check upon the program being too severe, the best guide is the sudden lassitude and indisposition of the boy who says, "I don't feel like doing the run or the test." Wisdom lies here in never "forcing" a boy to do what he feels indisposed to do. This is our policy. Occasionally a boy may be referred to the testing laboratory to see whether his cardiovascular tests reflect persistent fatigue of the autonomic nervous system. We have shown that boys rebound in a few days, at least in a week or two, from such fatigue (or what Dr. Ernst Jokl calls "athlete's indisposition").

To develop better cardiovascular condition, the training methods used for racing sports against time are generally the best; and we have shown that steeplechase training, interval training, obstacle courses, circuit training, and continuous muscular endurance exercises are better for stamina and circulatory-respiratory development than mild games of an intermittent nature. Endurance athletes generally have better circulatory-respiratory fitness at all ages than sprinters, jumpers, or games players. It is important to know that higher and higher levels of circulatory-respiratory fitness cannot be developed without repetitious endurance work, alternating "fatigue" with rest, food, and sleep. The training work is deliberately alternated many times in the "interval training" plan. It is possible to overtrain an individual, too, by giving more work than he can adjust to; but experienced physical education instructors and coaches are not apt to abuse boys. They take every

precaution to avoid severe upset of the autonomic nervous system. The warning signs are easily noted. Such "protective" symptoms are readily recognized: nausea, sleeplessness, loss of appetite, palpitation of the heart, sensitive blood pressures, and unusually fast pulse rate. More technically, the amplitude of the ECG chest *T* and *R* waves, the heartograph, and BCG may also be employed as a check upon overtraining and nervous exhaustion, as the amplitude of these measurements systematically declines in the state of persistent fatigue.

Research Studies on Endurance and Circulatory-Respiratory Fitness

Cureton (49) and associates analyzed 28 muscular endurance events and found that the tests were fairly specific for the extensor muscles of the arm, as contrasted with the flexor muscles of the arms—that these were still different from the endurance of the thigh flexor and extensor muscles acting in running—that muscular endurance of the feet and legs in hopping is quite different because of the heavy overload of the foot, leg, and thigh muscles and the low oxygen intake requirement. In events like the mile there is a strong circulatory-respiratory component.

McCloy (109) demonstrated in a factor analysis that *strength endurance* is different from *circulatory-respiratory endurance*. This study suggests that heavy overload exercise against resistance is dominated by neuromuscular patterns of muscular tension which will usually impede circulation; whereas circulatory-respiratory fitness is dominated by long continued, low resistance exercise which permits a maximum blood flow and oxygen intake during the exercise. This is greatly assisted by proper breathing. Asmussen (6) also confirmed this principle.

Cureton (31) demonstrated in a factor analysis that strength and motor performance components factor out quite differently from circulatory-respiratory variables. Strength, as measured on dynamometers, has no systematic relation to cardiovascular fitness. Strength is neuromuscular and can function for a short period of time independently of blood flow.

Robinson (132) demonstrated that the oxygen intake capacity per unit of weight is as adequate for preadolescent boys as it is for postadolescent boys. This has been supported by other studies (134).

Cureton, Doroschuk, Bernauer, and Bosco (48) demonstrated that all-out treadmill running time, 7 miles per hour, 8.6 per cent grade, could be predicted with multiple correlations as high as .95 from oxygen intake and rate of oxygen debt data. Endurance is shown to be highly related to blood flow and oxygen availability.

Several factor analyses have shown that there are at least eight factors in cardiovascular condition and even more when certain respiratory tests

are included, but no one test measures all of these factors. The best study is probably that of Sterling and Cureton (149) which identifies eight factors. It is clear that improvements should be measured in terms of each one of the following factors:

Velocity (and force) of heart ejection stroke and autonomic tone in the quiet state by brachial pulse wave or ballistocardiograph.

Splanchnic tone by change in pulse rate, pulse pressure, and brachial pulse wave, comparing sitting with standing measures.

Vagus tone by pulse rate in the quiet state and recuperation pulse rate after moderate standardized exercise.

Circulatory adjustment to moderate (submaximal) work by (24 steps per minute) simplified or progressive pulse ratio test.

Blood pressure adjustment to hard (maximal) work.

All-out treadmill (or step test) run time and associated oxygen intake.

Aerobic oxygen intake and estimation of gross circulation rate in all-out treadmill run (or all-out step test).

Total metabolic cost of all-out treadmill run (or all-out step test) by sum of oxygen intake and oxygen debt converted to calories per hour.

Astrand (9) demonstrated that oxygen intake capacity is higher for boys than for girls; for this reason the average endurance run should be about that much better for boys than for girls, as it turns out to be.

Several studies show that attitudes are much better among parents and instructors and that there is now general agreement, over several years of experimentation, that young boys can take a great deal more training than was commonly believed and that their adaptation capacity to endurance is even better than that of adults. This is supported by studies of Jokl (80), Karpovich (84), Fait and McCloy (60), Johnson (77), and the experience of many veteran coaches who have trained young boys and girls, as evidenced by the testimony of many coaches.

There is some lag in circulatory-respiratory fitness at approximately 11 years of age for boys, and there is some marked pick-up following the onset of the post-adolescent period, but it is believed that these differences are minimized by training begun earlier. Improved attitudes toward endurance work for youngters have been reported in several studies, especially those by Scott (140), Skubic (145), and McGee (111). Perhaps this improved understanding is being enhanced by good articles which show the great importance of stress in progressive training as necessary for the improvement of endurance and circulatory-respiratory fitness. Helpful aspects of gradually induces stress are reported by Ulrich (155), Johnson (77), Jokl (80), Barry (10), and many others. A committee of the Research Council for

Health, Physical Education, and Recreation concluded a four-year study in 1956 for prospective evidence of permanent damage to youngsters associated with overwork in endurance and competitive sports and found no such examples or evidence which could be sustained.

Some Hints Related to Developing Endurance

From over ten years of constant experimentation to improve stamina and circulatory-respiratory fitness in young boys, we make the following suggestions and comments:

Several weeks are needed for training boys to adjust to a fairly vigorous program. Some do not adjust fully even in eight weeks, but adjustment is usually possible if the endurance program is very gradually increased in dosage and intensity. Temporary fatigue is eliminated in a few days of rest. The formula is work-rest-work-rest, etc.

Every endurance drill should be accompanied by definite effort to breathe well, and deep breathing should be stressed following every work performance.

Motivation to "standards" is constantly needed, including participation and demonstration by the instructors. Rating tables are used for all endurance events.

Overeating should be avoided. Animal fat, chocolate, rich foods, soda pop, and all fried foods should be curtailed and emphasis placed on an abundance of vegetables, dried fruits, fresh and stewed fruits, fruit juices, green beans and peas, soy beans, black-eyed peas, lean meats, and whole-grain cereals, bolstered with salads, vitamins, wheat germ, and wheat germ oil (44, 51).

Some competition is needed, including competition with relative grades or scores in the endurance tables and in the cardiovascular tests, that is, competition against one's own score.

The best events to develop circulatory-respiratory endurance so far known include (a) steeplechase running, (b) continuous muscular endurance exercises done for 30 minutes without stopping, (c) interval training in track, running, cycling, swimming, skating, rowing, and taking tests in endurance runs (300-yard shuttle run, 300/60-yard drop-off ratio, 600-yard run on the treadmill and track, cross-country running and treadmill and track, cross-country running and circuit training) (42, 43, 86, 119, 121, 147).

Endurance will steadily improve over several months or several years but it will usually not improve in connection with skill-centered games and sport instruction. It will usually not improve in weight-lifting, statical tension exercises, or tense or emotional situations (6, 157).

Temporary setbacks may be expected if the program is too hard at first. Great care is needed to graduate the program and to provide regular alter-

nation of work with rest intervals, along with great emphasis on deep breathing to aid the circulation and to train the respiratory muscles. The ventilatory volume in work is relatively very great for top endurance athletes.

Relatively more sleep is needed with the practice of endurance programs. A rest in the middle of the day is also recommended, especially between morning and afternoon workouts.

Moderation is advocated in the intake of water, milk, and ice cream. Hold to one serving at any meal. Lemonade, limeade, orangeade, and skim milk are considered relatively better for emphasis during regular programs for training for endurance. Emphasis is placed upon real fruit and milk drinks rather than imitation (dyed) orange drinks, soda pop, or ice cream sodas.

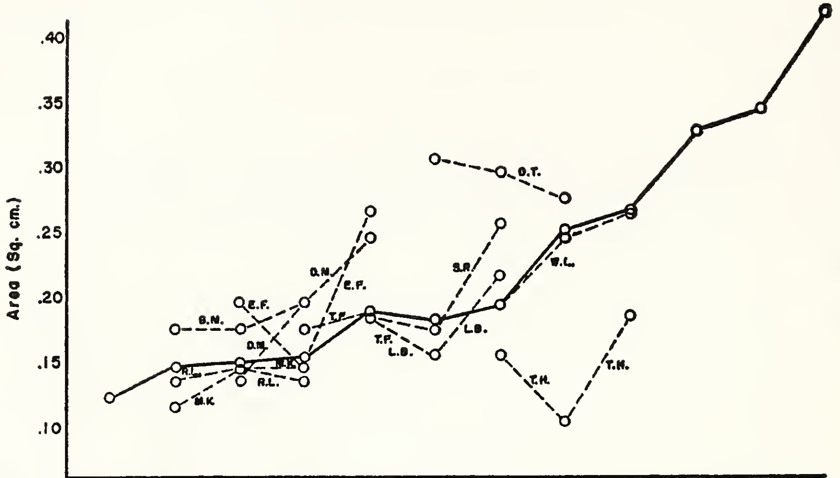
VII

CHANGES IN CIRCULATORY-RESPIRATORY FITNESS IN YOUNG BOYS ASSOCIATED WITH SPORTS AND ENDURANCE TRAINING PROGRAMS

It is now possible to classify groups for endurance training according to the relative stability or instability and capacity in the nervous system and/or responsiveness of the circulation rather than postexercise measurements. This means that the effect of certain test exercises, and also the recuperation effect, is noted. The primary objective of endurance training is to improve cardiovascular fitness and performance and also to improve recuperative capacity.

The contribution that school programs of physical education make to the maintenance and development of circulatory-respiratory fitness is not well understood. In spite of the extensive work of Robinson (132), Jokl (81), and Astrand (8), considerable ambiguity surrounds both the nature of the training required to produce measurable circulatory-respiratory changes and the upper limits of endurance performance in children. This chapter deals with both these problems. Especially does the chapter apply to the relative emphasis that should be given to skill training compared with endurance training in the physical education program if, as is frequently claimed, organic development is one of the main objectives of such programs, and if circulatory-respiratory fitness can be developed only by endurance patterns of work.

The first study in the area of the circulatory-respiratory fitness of young boys in which we were involved concerned the changes associated with a gymnastics program lasting eight months. The class, which was only indirectly associated with the Summer Sports-Fitness Day School, met once each week for approximately one hour, the first half hour being devoted to the learning of elementary tumbling stunts and the second half hour to the acquisition of skills on the trampoline. Wickstrom (162) studied the changes associated with this program in 12 boys 5 to 11 years of age with three aspects of the progressive pulse ratio test as the criterion of cardiovascular fitness (the average pulse ratio, angle of inclination, and the angle between the 30 and 36 steps per minute ratios). The program of gymnastics lasted 30 weeks with principal emphasis upon skill instruction. One subject improved significantly in the pulse ratio, two showed improvements in the average angle of inclination, and four improved in the 30 to 36 step ratios.



Age in Years	6	7	8	9	10	11	12	13	14	15	16	17
Mean	.127	.150	.156	.158	.193	.186	.197	.256	.271	.333	.350	.422
6	.031	.048	.065	.095	.054	.058	.080	.099	.105	.143	.112	.128
Number of Cases	7	31	48	48	33	36	54	61	68	32	32	20

FIGURE 63—Area of brachial pulse wave: pre- to post-training scores related to age performance curve.

Group analysis of the data, however, revealed no statistically significant mean difference. This shows the difficulty of averaging some subjects who improve with several who do not improve.

Roby (133) reported the changes in ECG recordings for the same subjects. The mean differences for all the ECG changes were statistically insignificant, which led Roby to conclude that a gymnastics program was unsuitable for producing statistically significant changes in ECG tracings, although such changes have been obtained in programs of endurance training involving strenuous cycling, swimming, and running. Wright (165) reached a similar conclusion after analysis of various measurements taken from the brachial pulse waves (heartographs) of the same group (Figure 63). Although one individual showed statistically significant improvements in all measurements, the cardiovascular fitness of this gymnastic group of boys was not improved as an average. The tentative conclusion is that gymnastics is too intermittent, composed of short and rather strenuous efforts which do not last long enough to give real impetus to the entire circulation, and is very different from the continuous "pumping" action of the rhythmic movements of swimming and running.

Bell's (14) study on the 1953–54 data from the Pond Gymnastics School similarly showed indefinite results of gymnastics training on the Schneider index and subparts thereof. No significant change was made in the time

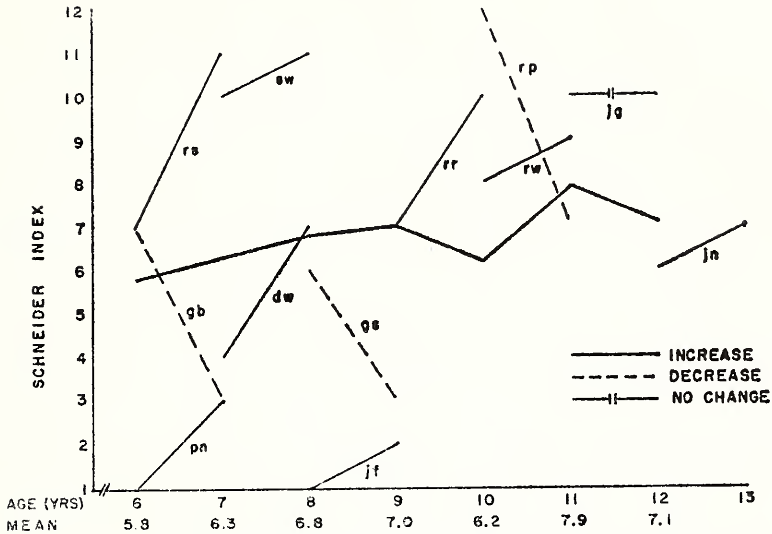


FIGURE 64—Schneider index: pre- and post-gymnastics training changes (Bell, 1958).

for the pulse rate to return or in the Schneider index as a whole. But three out of twelve boys improved the Schneider index significantly (Figure 64). The results indicated a large amount of individual variability, indicated as follows: Six subjects improved (lowered) the lying pulse rate, four showed no change, and two showed slight loss of cardiovascular condition. Six subjects improved in standing pulse rate, four showed a loss, and two remained the same. Seven subjects showed increased stability between lying and standing blood pressure, while five subjects lost stability. Seven subjects improved their scores for pulse rate immediately after exercise, four lost, and one remained the same.

The conclusion is that this type of gymnastics program was not sufficient in the sustained endurance type of work, nor was it long enough and hard enough to improve these particular cardiovascular measures. However, it is clear that the boys improved considerably in skills (Table 18).

These findings, together with the insignificant endurance changes from several studies completed in the years 1951–54, were responsible for the progressive increases in the dosage of endurance training in the Sports-Fitness School during the years following, 1955–60, the search being always for the way to improve endurance and cardiovascular fitness. The efficacy of these evolutionary trends in endurance training, as reflected in the data of several pertinent studies, is summarized below (cf. Chap. VIII).

TABLE 18

Pre-Season and Post-Season Comparison of Schneider Test Variables*
(Gymnastics Program)

Variable	T_1	T_2	*Diff.*	SE_M	*CR*	*Level of Significance*
Lying pulse rate (beats)	87	83.5	−3.5	7.82	0.477	*ns*
Standing pulse rate (beats)	102.0	102.8	0.8	11.49	0.69	*ns*
Lying systolic blood pressure (mm. Hg)	97.8	93.7	−4.1	5.85	0.70	*ns*
Standing systolic blood pressure (mm. Hg)	94.5	90.2	−4.3	7.14	0.60	*ns*
Pulse rate average just after exercise (beats)	18.7	13.7	−5.0	11.44	0.437	*ns*
Time of recovery of pulse rate to normal (sec.)	55.0	50.0	−5.0	47.77	0.104	*ns*
Schneider index	6.6	6.8	0.2	3.16	0.063	*ns*

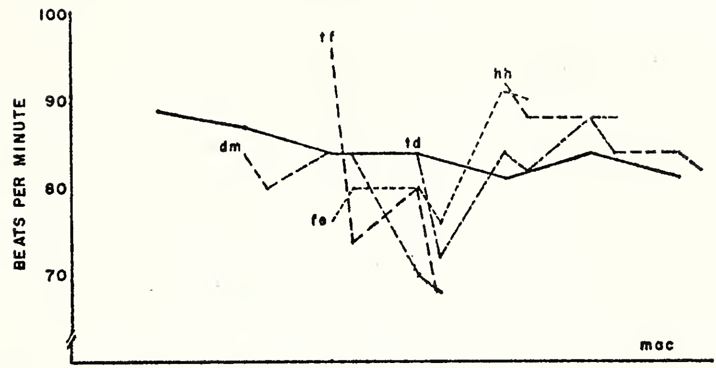
* From Bell's study; data from Pond's Gymnastic School, 12 boys, 5 to 11 years of age.

Certain boys improve as individuals and others do not, this variability usually giving an insignificant statistical change for the whole group. Some boys work harder than others in the very same periods, and differences of constitutional type and biological individuality are obvious. Perhaps the program was too hard for a few boys; at least they needed a longer time to make full psychological and physiological adjustments to the program. In most performance tests the test results reveal only what the boy is willing to do. A highly motivated boy may outdo a larger, stronger, and more skillful boy in stamina events if the latter does not want to do the test.

PULSE RATE AND BLOOD PRESSURE TESTS

The normal heart rate response to persistent endurance training over several weeks is for a decrease to occur, although this has not been found consistently in all of the present data, as individual cases followed over three summers indicate (Figures 65, 66). Where increases occur, as for example in the case of F.E., it is probably due to lack of quick adjustment to the unaccustomed stress of training, associated with a labile nervous system sensitive to stress. Persistent but gradual progressive training toughens the nervous system to stress. Great variability in the cardiovascular responses of young boys is found generally throughout the quiet (T_2) tests given at the end of the eight-week season.

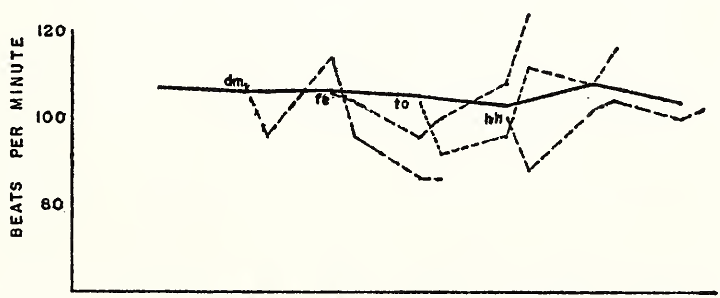
Holmes (71) studied the effects of four endurance training programs on several measurements of cardiovascular fitness in four matched groups of boys 6 to 14 years of age with 19 boys in each group. The four programs



AGE (YRS.)	7	8	9	10	11	12	13
MEAN	89	87	84	84	81	84	81
NUMBER	52	69	66	53	35	22	15
σ	10.4	9.3	9.0	10.4	10.3	8.9	13.4

FIGURE 65—Lying pulse rate: pre- and post-training scores related to norm curve.

(circuit training, muscular endurance exercises, interval running, and steeplechase) had been added to the regular program in the Sports-Fitness School and were carried out for 30 minutes each day over the eight weeks by four matched groups (grouped and matched for age and 600-yard run time), simultaneously in parallel training groups. The work was done on the same field under the same weather conditions and with the same amount of time spent on each group. The results of the pretraining and post-training tests for the 5-minute step test are shown in Table 19, where the longer



AGE (YRS.)	7	8	9	10	11	12	13
MEAN	107	106	106.5	105	103	108	103.5
NUMBER	52	67	62	47	35	26	15
σ	13.7	11.4	10.4	11.0	15.1	11.4	15.0

FIGURE 66—Standing pulse rate: pre- and post-training test scores related to norm curve.

TABLE 19

Changes in Recuperation Pulse Count (5-Step Test) with Four Types of Training (Holmes)

	Raw Score Means			Standard Score Means		
Training Method	T_1	T_2	*Diff.*	T_1	T_2	*Diff.*
Circuit training	177.17	176.42	− 0.75	27.17	27.92	0.74
Muscular endurance	176.21	173.36	− 2.85	28.07	30.50	2.43
Interval running	174.56	166.81	− 7.75	29.56	35.87	6.31
Steeplechase	172.21	160.29	−11.92	31.29	41.36	10.07

NOTE.—One minute after stepping up and down on a 14-inch bench for 5 minutes, the pulse beats are counted: (a) 1:00 to 1:30, (b) 2:00 to 2:30, (c) 3:00 to 3:30; and these three 30-second counts are summed for the raw score in the table. $N = 19$ boys in each group.

running programs (interval running and steeplechase) are shown to be more effective in reducing postexercise pulse rates (sum of three half-minute counts) than circuit training or muscular endurance exercises.

Other studies (35, 118, 135, 164) show insignificant changes associated with casual recreational play types of programs. A baseball season produced only one significant change (pulse pressure) out of 25 cardiovascular test variables; volleyball failed to produce significant cardiovascular changes; a season of basketball produced no significant cardiovascular changes in one group, and in another no significant ballistocardiographic changes. It was noted, however, that changes were obtained in the preseason and early season but these were generally nullified by accumulative fatigue toward the end of the playing season.

In two follow-up studies Powell (129) and Pattee (125) revealed increases in both lying and standing systolic blood pressures after persistent training, showing that the training resulted temporarily in higher internal vascular tension (Tables 20, 21). Where the diastolic blood pressure decreases, with an accompanying increase in pulse pressure, it is likely that the individual has made a satisfactory adjustment to the training; and, conversely, with an increase in diastolic pressure and a decrease in pulse pressure he is still struggling to adjust to the training. This adjustment is a matter of time and of enough rest for the work done, apportioned properly day by day and week by week as the work progresses.

In contrast to the increases in systolic blood pressure noted in the above follow-up studies, the curves of four boys followed over three summers reveal decreases over the summer school period and increases through the remainder of the year (Figures 67, 68). This is probably due again to fatigue at the time of the final (T_2) testing.

Table 20

Raw Score Changes in Cardiovascular-Respiratory Fitness Associated with Rope-Skipping (Powell)

Test	*Subject A* (Age 10-8)		*Subject B* (Age 10-0)		*Subject C* (Age 9-10)		*Subject D* (Age 10-11)		*Subject E* (Age 11-3)	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
Vital capacity at 37° (cu. in.)	107	185	75	161	86	172	86	165	64	150
Vital capacity residual (cu. in.)	−34	38	−26	54	1	74	−52	27	−130	−56
Post-run (2 min.) breath-holding (sec.)	8.0	25.0	5.0	29.0	20.0	30.0	15.0	18.0	10.0	15.0
Sitting oxygen intake (cal/hr/sq m)	44.3	44.6	40.7	60.0	47.70	67.70	21.41	22.90	49.1	51.6
Post-exercise pulse rate (beats/min)*	127	140	176	160	182	174	147	170	156	180
600-yard run time (sec.)	134.0	123.0	149.0	147.0	143.0	125.0	173.0	157.0	220.0	190.0
Treadmill run time (min.:sec.)*	10:03	13:08	11:35	10:00	10:33	15:08	2:28	2:55	2:00	2:28
Lying pulse rate (beats/min)	84	80	86	88	84	66	88	88	74	84
Standing pulse rate (beats/min)	100	100	108	100	104	74	112	112	110	110
Lying systolic blood pressure (mm. Hg)	98	106	100	100	98	88	86	100	105	108
Standing systolic blood pressure (mm. Hg)	96	106	96	104	84	90	82	108	92	112
Lying diastolic blood pressure (mm. Hg)	64	68	58	55	70	60	50	50	68	80
Standing diastolic blood pressure (mm. Hg)	70	60	70	60	52	60	68	60	68	80
Schneider index (points)	9	10	4	10	5	17	7	6	1	6
5-min. step test (beats)	183	160	210	154	158	162	180	180	210	180
Pulse wave area (sq. cm.)	0.10	0.15	0.10	0.14	0.10	0.14	0.06	0.11	0.19	0.29
Pulse wave, systolic amplitude (cm.)	0.01	0.50	0.03	0.50	0.36	0.43	0.30	0.42	0.20	0.89
Pulse wave, diastolic amplitude (cm.)	0.00	0.35	0.20	0.30	0.19	0.20	0.10	0.20	0.20	0.54
ECG *T* wave amplitude (mm.) lead V	8.70	11.50	4.6	6.0	6.0	6.8	8.6	8.6	4.2	7.3
ECG *R* wave amplitude (mm.) lead V	23.10	15.30	17.1	15.6	11.6	8.6	24.3	22.8	4.0	6.5

* All-out treadmill run, 5 m.p.h., 8.6 per cent grade, min.:sec.

TABLE 21

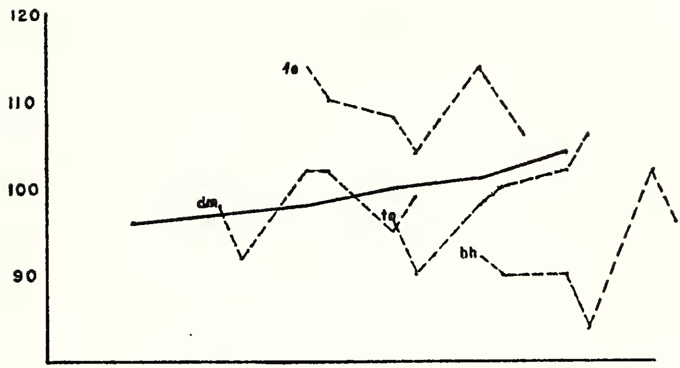
Changes in Cardiovascular-Respiratory Fitness Associated with a 13-Week Running and Muscular-Endurance Exercise Program (3 Subjects—Pattee)

	Subject A (Age 10-9)			*Subject B* (Age 10-7)			*Subject C* (Age 10-9)		
	T_1	T_2	SS Gain	T_1	T_2	SS Gain	T_1	T_2	SS Gain
Vital capacity at 37° (cu. in.)	120	154	35	159	175	18	159	222	23
Vital capacity resid. (cu. in.)	0	7	4	17	22	3	−32	16	23
Post-exerc. br'th-hold. (sec.)	12.0	20.0	18	7.0	13.0	12	10.0	15.0	9
Expir. force (mm. Hg)	70	130	36	60	112	30	126	190	36
Sitting O_2 intake (l/min) ..	.220	.196	..	.183	.208	..	.284	.267	..
Ex. O_2 intake (l/min)* ...	1.356	1.289	..	1.308	1.344	..	2.116	1.913	..
Ex. O_2 intake (l/min/kg)*	.0409	.0364	..	.0346	.0337	..	.0455	.0381	..
Treadm. run time (min:sec)*	5:00	10:00	24	3:00	3:00	0	2:15	4:56	14
600-yard run time (sec.) ...	126.0	126.0	0	164.0	156.0	8	142.0	138.0	2
Lying pulse rate (beats/min)	64	60	6	78	64	24	74	64	18
Stand. pulse rate (beats/min)	70	72	− 2	100	100	0	84	92	−12
Lying systol. bl. p. (mm. Hg)	102	104	2	102	110	−10	100	108	−10
Stand. systol. bl. p. (mm. Hg)	100	106	9	90	110	−24	108	110	− 2
Lying diast. bl. p. (mm. Hg)	44	44	0	62	52	17	52	58	−10
Stand. diast. bl. p. (mm. Hg)	58	60	− 2	60	60	0	70	74	− 6
Schneider index (points) ...	18	15	−10	9	11	15	13	8	−30
Pulse wave area (sq. in.) ...	0.10	0.20	30	0.15	0.08	−20	0.15	0.20	15
Pulse wave syst. ampl. (cm.)	0.50	0.76	23	0.87	0.68	−16	0.67	0.87	17
Pulse wave diast. ampl. (cm.)	0.30	0.54	28	0.33	0.40	9	0.30	0.44	16
ECG *T* wave am. (mm.) ld.V	8.5	13.6	28	9.0	10.0	5	11.9	9.0	−11
ECG *R* wave am. (mm.) ld.V	23.1	29.6	19	32.4	32.4	0	26.5	37.2	32

* All-out treadmill run at 5 m.p.h., 8.6 per cent grade.

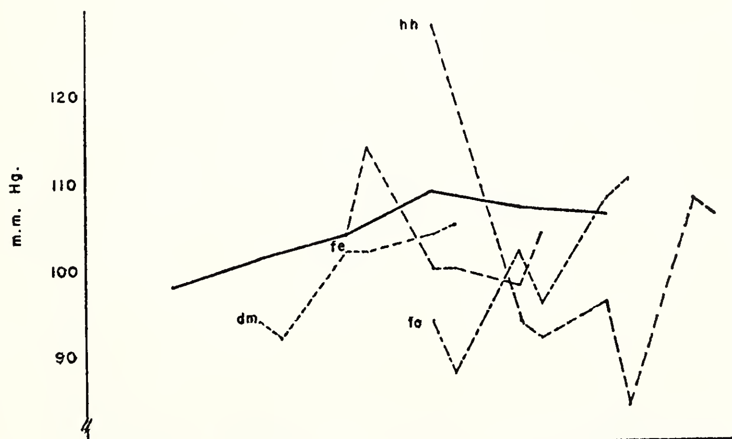
A similar decrease in T_2 circulatory test scores is seen in the Schneider index and Crampton index results of the matched groups in Holmes's (71) study (Tables 22, 23). Holmes concluded that the losses in these tests were proportional to the fatigue induced by the various programs and attributed them to a temporary fatigue and instability in the autonomic nervous system. This is common and is to be expected in the early stage of training.

With one year of school and extracurricular physical activity intervening between two summer schools, DiOrio (54) found that ten subjects improved their Schneider indexes more than the anticipated growth change, and five retrogressed. The Schneider and Crampton indexes are apparently quite sensitive to imbalance of the autonomic nervous system, and group analyses of data from these and similar tests usually reveal mean differences between T_1 and T_2 of around zero. The results for the Schneider index in the two follow-up studies by Powell (129) and Pattee (125) (Table 20, 21), wherein



AGE (YRS.)	7	8	9	10	11	12	13
MEAN	96	97	98	100	101	104	
NUMBER	26	30	37	23	42	44	
σ	7.7	6.9	7.6	7.5	4.6	5.9	

FIGURE 67—Lying systolic blood pressure: pre- and post-training test scores related to norm curve.



AGE	7	8	9	10	11	12	13
MEAN	98	101	104	109	107	106	
NUMBER	26	30	31	73	42	43	
σ	9.6	36.2	7.8	7.1	5.6	5.8	

FIGURE 68—Standing systolic blood pressure: pre- and post-training test scores related to norm curve.

TABLE 22

Changes in Schneider Index with Four Types of Training (Holmes)

	Raw Score Means (points)			Standard Score Means		
Training Method	T_1	T_2	*Diff.*	T_1	T_2	*Diff.*
Circuit training	5.95	5.77	— 0.22	47.63	46.58	— 1.05
Muscular endurance	5.78	6.50	0.72	48.61	51.67	3.06
Interval running	7.61	5.94	— 1.67	60.55	49.72	—10.83
Steeplechase	8.00	8.06	0.06	57.50	58.75	1.25

five boys show a mean gain of 21.4 standard scores and three boys a mean loss of 14.2 standard scores, support this point. From the point of view of adjusting the training load, the desirability of detecting boys with labile nervous systems is apparent. At least early fatique can be expected in these boys. There is no known way to induce improvement in endurance and cardiovascular condition except by the alternation of fatigue, rest, fatigue, rest, etc., until adjustment occurs (13).

Marsh (113) demonstrated the validity of a hard progressive training program of warm-up (near all-out) muscular endurance exercises and one hour of continuous cycling (13 weeks of a two-hour program on Saturday morning) to produce marked improvements in circulatory-respiratory fitness. Four boys, two 9 and two 10 years of age, were used in the experiment, conducted at the University of Illinois, from February 8 to May 3, 1958. In addition to the Saturday morning program, the boys practiced at home each day, five other days per week, for 30 to 45 minutes, imitating the Saturday morning program as to pace and distance of the cycling. The results showed that (cf. Table 24) (a) the expiratory force increased in all four cases—26, 10, 30, and 48 mm. Hg; (b) the vital capacity improved in all four cases—13, 7, 21, and 46 cu. in.; (c) the breath-holding ability increased 1, 7, 3, and 15 sec.; (d) the heartograph measures improved in

TABLE 23

Changes in Crampton Index with Four Types of Training (Holmes)

	Raw Score Means (points)			Standard Score Means		
Training Method	T_1	T_2	*Diff.*	T_1	T_2	*Diff.*
Circuit training	54.21	53.68	— 0.53	37.47	37.37	— 0.10
Muscular endurance	54.44	55.28	0.84	37.72	38.39	0.67
Interval running	56.39	52.78	— 3.61	39.44	36.39	— 3.05
Steeplechase	61.47	55.88	— 5.59	43.76	38.88	— 4.88

TABLE 24

Improvements in Circulatory-Respiratory Tests with Training*
(Progressive Cycling Program)

Test	*Subject A*	*Subject B*	*Subject C*	*Subject D*	*Average Improvement*
Expiratory force blow ...	12	5	14	23	13.5
Vital capacity on spirometer	12	36	21	46	28.75
Breath-holding 2 min. after exercise	8	51	7	43	27.25
Five-minute step test	8	15	9	4	9.0
Heartometer brachial pulse wave (area)	5	8	22	9	11.0
Heartometer brachial pulse wave (systolic amplitude)	12	12	11	3	9.5
Heartometer brachial pulse wave (diastolic amplitude)	16	21	17	10	16.0
Heartometer brachial pulse wave (obliquity angle)	17	7	57	3	21.0
Progressive pulse ratio (angle between 24- and 30-step increment)	30	57	3	24	28.5
Total pulse count (30 steps/min)	9	16	− 1	− 5	4.75
Electrocardiogram, *T* wave amplitude (5th highest precordial lead)	18	23	14	7	15.4
Electrocardiogram, *R* wave amplitude (highest precordial lead)	9	10	−22	21	19.5
All-out treadmill run (5 m.p.h., 8.6% grade)	− 2 (4:57–4:30)	37 (6:15–13:00)	49 (10:36–21:10)	8 (4:51–6:30)	23.0
All-out 4-item muscular endurance test	40	184	207	123	138.5

* 13-week mixed program of hard warm-up (near all-out) endurance exercises and progressive training in cycling for one hour continuously. Four subjects; all gains in standard scores. (Marsh)

all four, indicating a stronger heart stroke (ejection velocity); (e) the progressive pulse ratio improved in all four, indicating more efficient recovery from work; (f) two required fewer beats of the heart for the same work and two were not better in this respect but remained about the same; (g)

the electrocardiogram increased the amplitude of the highest precordial *T* wave, 2.9, 3.5, 2.8, and 1.1 mm.; (h) the ECG *R* wave increased in three subjects, 20.3, 4.2, and 3.9 mm. and decreased 6.0 in one (the latter showing some fatigue); (i) the all-out treadmill run at 5 mi./hr., 8.6 per cent grade, improved in three (6:45, 10:34, 1:39) and reduced in one subject 27 sec.

Brachial Pulse Wave

The action of the heart and state of the blood vessels, as reflected in the systolic amplitude, obliquity angle, and area of the brachial pulse wave, are influenced more by endurance training programs than was found to be the case with the gymnastic training program (165). In DiOrio's (54) study of the changes occurring over one year, seven boys increased beyond the normal growth expectancy in area under the curve of the pulse wave, three remained the same, and four decreased. The mean group change of 0.019 sq. cm. was not statistically significant. Eleven boys showed improvements in obliquity angle, the decrease in the angle of 2.6° being highly significant. In systolic amplitude, seven of the 14 subjects improved with a mean increase of 0.065 cm., which was highly significant.

In the matched group study with endurance training variations, Holmes (71) found that longer distance running programs (steeplechase and interval running) gave greater improvements in systolic amplitude of the brachial pulse wave than either circuit training or muscular endurance exercises (Table 25). Marsh (113) reported an average gain of 0.165 cm. (12.25 S.S.) in four boys who combined all-out muscular exercises (as warm-up) with riding for one hour continuously, the speed being increased for the cycling every week for 13 weeks. These four subjects decreased the obliquity angle and increased the area under the brachial pulse wave. Pulse rate in the quiet sitting position reduced in three subjects and remained the same in one.

Substantial improvements were shown in the follow-up studies of Powell (129) and Pattee (125) with five and three subjects, respectively, in area

Table 25

Changes in Brachial Pulse Wave Systolic Amplitude with Four Types of Training (Holmes)

	Raw Score Means (cm.)			Standard Score Means		
Training Method	T_1	T_2	*Diff.*	T_1	T_2	*Diff.*
Circuit training	0.74	0.86	0.12	46.49	55.05	8.26
Muscular endurance	0.77	0.84	0.07	51.00	54.83	3.83
Interval running	0.65	0.82	0.17	42.78	55.00	12.22
Steeplechase	0.84	1.03	0.19	55.63	67.69	12.06

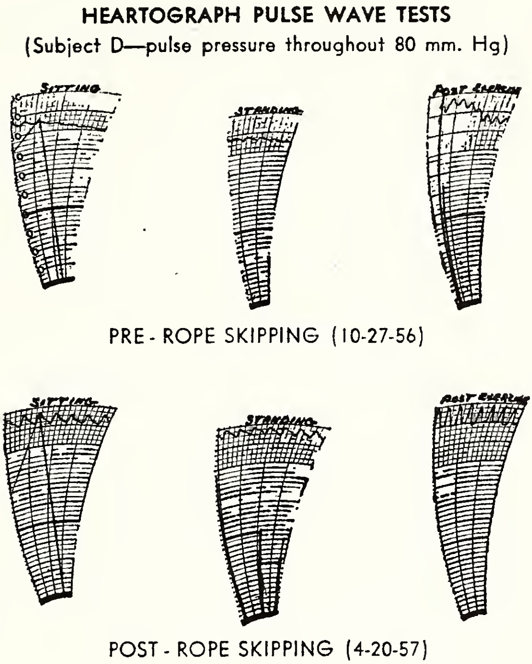


FIGURE 69—Example of improvement in the heartograph (brachial pulse wave) in a rope-skipping experiment.

under the curve and the pulse wave, systolic amplitude, and diastolic amplitude (Tables 20, 21). Such changes usually indicate increases in stroke volume and improvement in blood circulating capacity. It is interesting to note the relative contributions to circulatory fitness of the rope-skipping (Figure 69) and running programs conducted by Powell (129) and Pattee (125) compared with endurance exercises combined with strenuous cycling as reported by Marsh (113). Each of these programs consisted of approximately one hour of formal guidance and instruction per week, although the experimental nature of the first two probably facilitated motivation of the subjects to continue unsupervised daily practice in the training items, and this would have to be considered in evaluating the relative contributions of the three types of activity.

ELECTROCARDIOGRAPHIC CHANGES

Cureton (35, 42) has reviewed the evidence on changes in deflections of the *T* and *R* waves (highest precordial), concluding that "the highest

precordial T wave can be improved by hard physical training of the repetitive endurance or interval training type, with training five times per week for an hour or more. As the training programs become submaximal, there is little change in the T wave. The T wave builds up with training over 6 to 12 weeks but hard training without a break of a single week will lead to 'athletic staleness' characterized by reduced amplitude of the T wave and R wave of the ECG." It is important, then, in interpreting ECG training changes to distinguish between work loads that are insufficient (submaximal), adequate, or exhorbitant. During the initial stages of a training program, a temporary depression in the R wave and T wave is usually observed, which depression remains until physiological adaptation to the training takes place. These phenomena are apparent in the T-wave and R-wave curves of individual cases followed over three summers (Figures 70, 71), as well as in the group and case studies reported in this section.

In his study of 15 boys over two summers of training (1953 and 1954), DiOrio (54) found that only three boys improved in the amplitude of the R wave beyond the normal growth pattern, while nine decreased. Five improved and nine decreased in amplitude of the T wave. Thus ordinary sports instruction is ineffective without emphasis upon endurance training.

In a group analysis of the changes in amplitude of the T wave associated with four training variations (Table 26), Holmes (71) found no significant increases or decreases, although there was a trend for the amplitude to decrease in the case of the more strenuous forms of training (interval running and steeplechase). In interpreting these data, Holmes found it con-

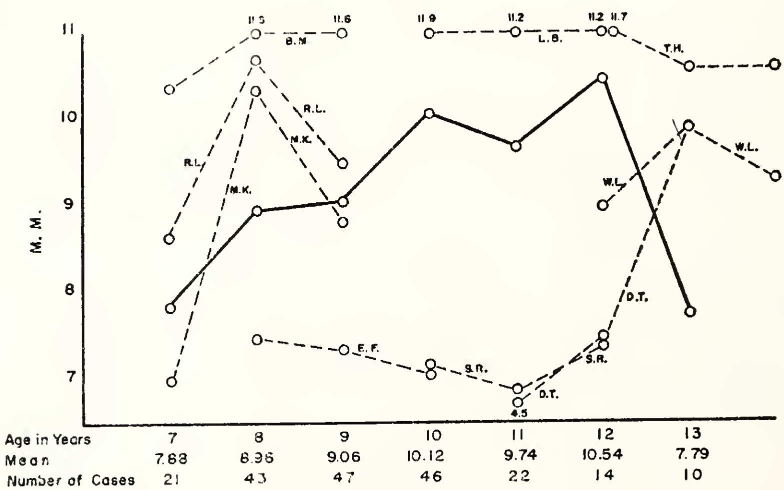
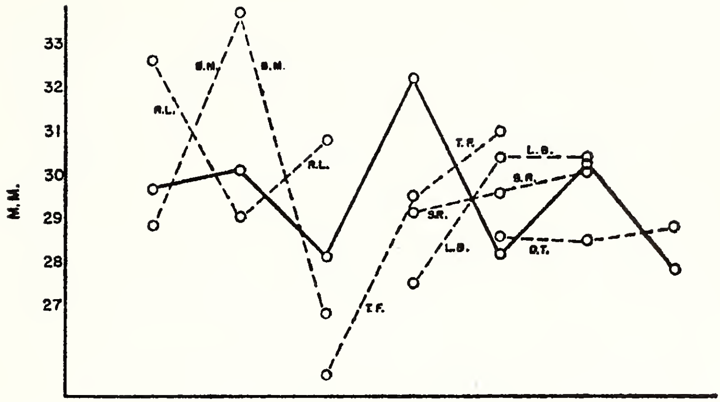


FIGURE 70—T-wave electrocardiogram: longitudinal changes related to norm curve.



Age in Years	7	8	9	10	11	12	13
Mean	29.75	30.17	28.18	32.33	28.30	30.36	27.89
Number of Cases	24	43	46	26	22	14	10

FIGURE 71—*R*-wave electrocardiogram: longitudinal changes related to norm curve.

venient to classify the seven tests used in his study into two groups, the first consisting of 600-yard run, "all-out" treadmill run, systolic amplitude of the pulse wave, and 5-minute step test, and the second comprising the Schneider and Crampton indexes and *T* wave of the ECG. The second group of tests appeared to be sensitive to the severity of the training, although it should be noted that such training, with its temporary transient fatigue effect, and combined with alternating periods of rest, is essential to the development of higher levels of organic fitness.

The fallacy in making group analyses of data pertaining to such sensitive indices as the ECG deflections may be deduced again from the results of the studies conducted by Powell and Pattee (Tables 20, 21). Where adap-

TABLE 26

Changes in ECG *T* Wave (Highest Precordial) with Four Types of Training

	Raw Score Means (mm.)			Standard Score Means		
Training Method	T_1	T_2	*Diff.*	T_1	T_2	*Diff.*
Circuit training	8.09	8.43	0.34	38.26	40.00	1.74
Muscular endurance	8.47	9.04	0.57	40.72	43.44	2.72
Interval running	9.04	8.84	− 0.20	43.33	42.78	− 0.55
Steeplechase	8.68	7.86	− 0.82	41.00	37.06	− 3.94

tation to the training has taken place, increases in the amplitude of the *T* wave and *R* wave may be noted, whereas decreases serve at the interpretive level to indicate the presence of transient fatigue, and at the computational level, to reduce any means to around zero. It is clear that, even with individual guidance, it has not been possible so far to calculate exact optimal work loads compatible with individual differences in the stability or non-stability of the nervous system.

TABLE 27

Changes in 600-Yard Run Time with Four Types of Training (Holmes)

	Raw Score Means (min:sec)			Standard Score Means		
Training Method	T_1	T_2	*Diff.*	T_1	T_2	*Diff.*
Circuit training	2:47	2:43	− 4.26	36.11	41.00	4.89
Muscular endurance	2:45	2:36	− 9.17	37.33	44.33	7.00
Interval running	2:48	2:41	− 7.00	36.00	41.39	5.39
Steeplechase	2:49	2:31	−18.13	36.07	50.40	14.33

PERFORMANCE TESTS

Improvements in 600-yard run performance and the "all-out" treadmill run test (5 and 7 m.p.h., 8.6 per cent grade) associated with four training variations are shown in Tables 27 and 28 (71). In the 600-yard run, the steeplechase group improved 14.3 standard scores, significantly more than the 4.9 standard score improvement of the circuit training group or the 5.4 standard score improvement of the interval training group. In endurance performance as reflected in the treadmill run, the 9.0 standard score improvement shown by the interval training group was significantly better than the 2.8 standard score improvement of the muscular endurance group. The superior performance of the interval training group is probably related to the fact that

TABLE 28

Changes in All-out Treadmill Run Time with Four Types of Training (Holmes)

	Raw Score Means			Standard Score Means		
Training Method	T_1	T_2	*Diff.*	T_1	T_2	*Diff.*
Circuit training	....	....	....	25.47	29.88	4.41
Muscular endurance	....	....	....	19.59	22.35	2.76
Interval running	....	....	....	22.78	13.78	—9.00
Steeplechase	....	....	....	24.78	32.33	7.58

NOTE.—No raw score means possible; different rates of speed dependent on age.

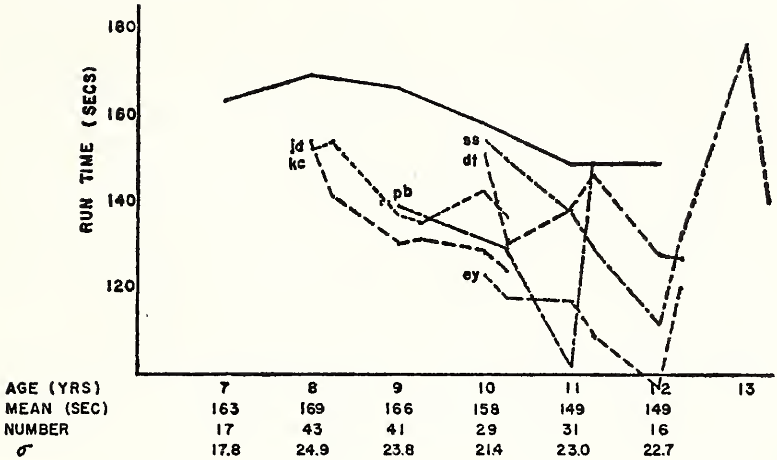


FIGURE 72—600-yard run: pre- and post-training test scores related to norm curve.

this group made the greatest improvements in over-all strength during the summer (27), which improvement may have facilitated the up-grade treadmill running.

The progressive changes in 600-yard run time in six subjects over three summers are shown in Figure 72. The most marked losses are associated

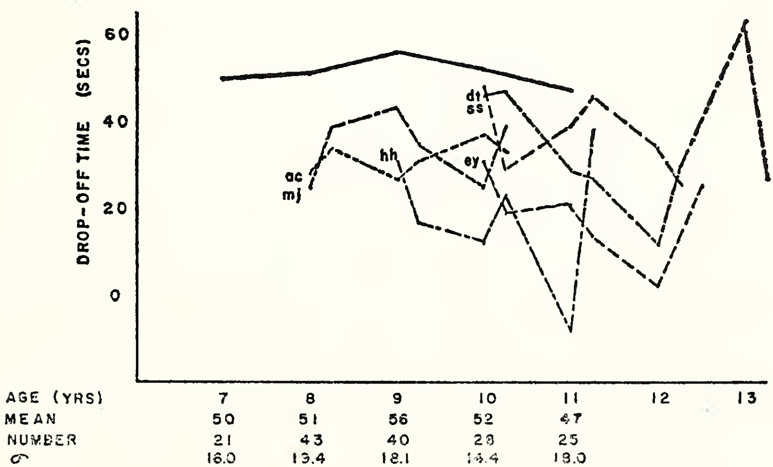


FIGURE 73—Drop-off index: pre- and post-training test scores related to norm curve.

with the early adolescent years (11 to 13). These losses are also shown in the "drop-off" index curves for the same subjects (Figure 73). The lack of adaptation to systematic training, especially in the first year of participation in the summer school, is apparent also.

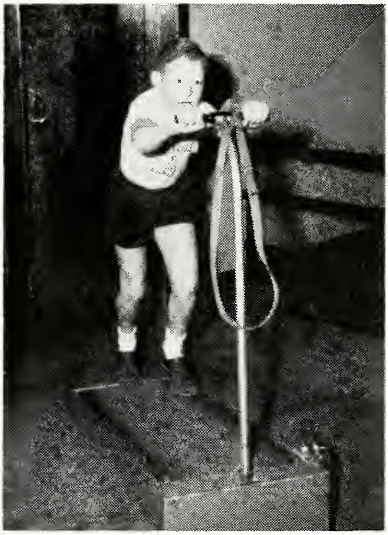
Respiratory Measures

The changes in respiratory fitness associated with two summers' participation in the Sports-Fitness Day School, together with one year of school and some extracurricular physical activity were studied by DiOrio (54) using 14 boys 8 to 10 years of age as subjects. Seven of the boys improved with respect to the age-norm curves in maximum expiratory blow, and seven retrogressed; the mean group increase of 9.5 mm. Hg was not statistically significant. In breath-holding after exercise (one minute of stool stepping at 30 steps per minute), nine subjects improved more than the anticipated growth change. The group mean increase of 1.41 seconds was significant (.05 level).

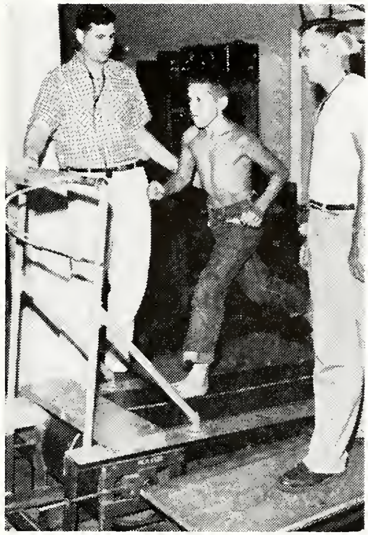
In the follow-up work conducted by Pattee (125) and Powell (129) with small groups, the former concerned with the changes induced by a 13-week running and muscular endurance exercise program and the latter with a 10-week rope-skipping program, marked improvements were shown by all subjects (three and five, respectively) in vital capacity residual, postexercise breath-holding (after two minutes of running in place) and expiratory force (Tables 20, 21). The maximal individual increases of 32 standard scores in vital capacity residual, 67 standard scores in postexercise breath-holding, and 36 standard scores in expiratory force are greater than those normally encountered in work with larger groups; that they should occur in association with training that was sustained shows the value of such endurance training.

Fatigue Due to Too Much Competition

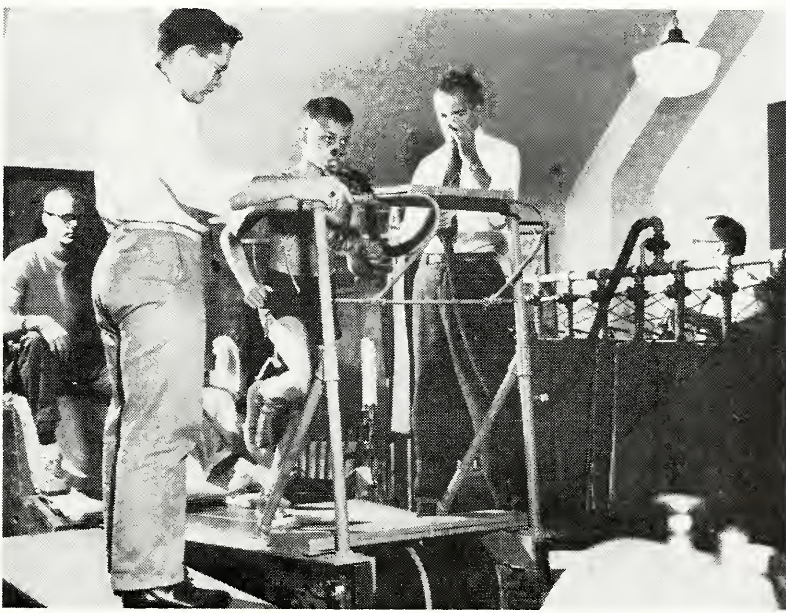
The final week of the eight-week course of training was always a very intensive one, including competitions in various sports between two sides, with interest at high level. The laboratory tests were conducted in the mornings and the sport competitions in the afternoons, but in certain boys fatigue was carried over into the next day. This conflict has now been partially obviated by the intramural contests being held in the 7th week and the laboratory tests in the 8th week. Even with this adjustment it was found that few boys could run an all-out treadmill run in the morning without loafing a bit in a 600-yard timed run in the afternoon of the same day. Brown (18a) and Doroschuk (55) both demonstrated that this was the main cause of a few boys doing poorly in their final trials. Retest of these boys after a week of rest produced much better times.



(a) Practice on the portable self-propelled treadmill.



(b) On the motor-driven treadmill.

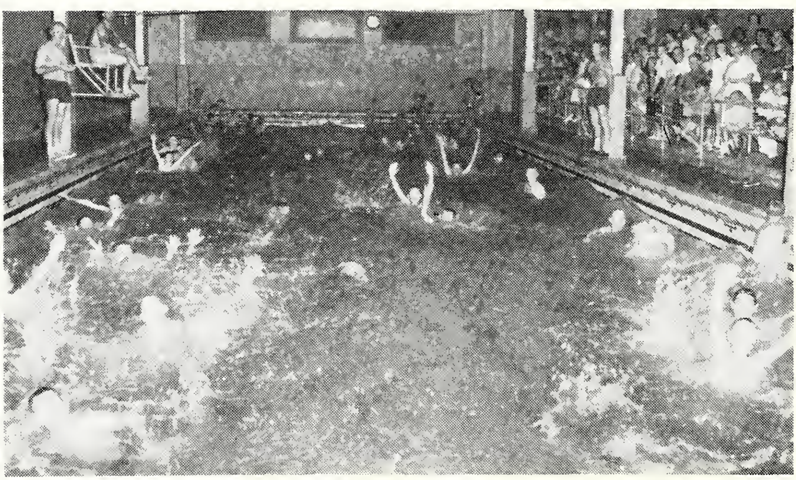


(c) William Orban, Jr. in an all-out treadmill run of quality.

PLATE XI—Physical Fitness Laboratory: treadmill.

(a) Sports-Fitness School boys play games, indoors and outdoors.

(b) Just after a mile run a 7-year-old gets his dietary supplements.



(c) Free swim after 3 hours of sports and the endurance mile-athon—Hurrah!

PLATE XII— Sports-Fitness School: activities and dietary supplements.

VIII

PERFORMANCE, PREDICTION, AND IMPROVEMENT IN THE ALL-OUT TREADMILL RUN AND THE 600-YARD RUN

A Criterion for Endurance

The all-out treadmill run has been used as a criterion for endurance in the University of Illinois Physical Fitness Research Laboratory. It simulates a short, hard athletic event lasting from 2 to 5 minutes for about 99 per cent of the subjects, corresponding to running from 300 to 1,000 yards up a slope of 8.6 per cent to virtual exhaustion. For this purpose it has been used for about 20 years at various laboratories in the United States. Because it imitates track work and carries over into running in various games, steeplechases, interval training, and obstacle courses, the treadmill run is more commonly used than the bicycle. (See Plate XI.)

The 600-yard run has been in use in the 4-H Club health program in the counties of Illinois for approximately 15 years. It has been used nationwide in the American Association for Health, Physical Education and Recreation's testing program related to "Operation Fitness" for the last five years (listed as Run-Walk). It is not an adequate measure for the longer runs, such as cross-country, 5,000 and 10,000 meters (or 3 miles or 6 miles) but is as long as is now generally approved. Our experience with this run has been satisfactory, there being virtually no complaints; but it has been shown that the treadmill run is somewhat more reliable with young boys than is the 600-yard run. Boys of 7 to 14 years do not have a trained sense of pace until they have run the 600-yard distance a few dozen times. There is a high correlation between the 600-yard run and the mile run. The latter was adopted first by the Boy Scouts of America during World War II, and standards were set up for this event in September, 1944, for use in the high schools of Illinois for 13- to 18-year-old boys (66).

Prediction of All-Out Treadmill Running

In 1948–49 all-out treadmill run data were collected on young men (18 to 25 years) and reduced to rectilinear form so that prediction equations could be made based on the best combination of gross oxygen intake and net oxygen debt. Cureton (33) found that dividing the liters of oxygen intake by the kilos of body weight (l/kg) reduced the data to linear form, and that the oxygen debt could also be used as a *rate of oxygen debt*

(l/min/kg). The best prediction equation to predict the all-out treadmill run at 10 mi/hr, 8.6 per cent grade was (rectilinear standard score regression equation) (38): time in run $= 0.75$ (gross oxygen intake in l/kg in S.S.) -0.46 (rate of oxygen debt in l/min/kg in S.S.); $R = 0.97 \pm PE_{(\text{est})}$ 0.17 min. (*Note:* The standard scores to be inserted are the $6\sigma/100$ type.)

The question is whether such work is feasible with young boys, 8 to 14 years, inclusive. Over four years of experimentation (1955, 1956, 1957, 1958) it was conclusively shown that young boys could adjust to progressive endurance work until they could do 30 minutes of paced work without stopping, and that such endurance work produced improvements in 600-yard running time on the track and also in all-out treadmill running relatively greater than the improvements which had been obtained in 1950, 1951, 1952, and 1953, when such endurance training was not given in a day by day progressive manner in a gradual build-up (39, 50).

The results coincide essentially with those of Jokl (80) reported in 1941. It is not surprising that young boys have as much oxygen intake capacity as postadolescent boys, such results having already been shown by Robinson (132) in 1939. Astrand (9) contends that aerobic oxygen intake capacity is probably the best measure of circulatory-respiratory function which is feasibly measured without arterial puncture as it is independent of will power. Robinson (132) and also Morse, Schultz, and Cassels (120) either used submaximal work or varied the speed of the treadmill so that all-out performances could not be compared at various ages. The work by Rohdahl *et al.* (134), involved all-out treadmill runs with findings similar to the Illinois results in oxygen intake capacity (48).

The treadmill test was designed as a hard effort to terminate in 5 minutes or less, to overload the muscles and circulatory system beyond the capacity to adjust to the steady state, and to require a run to temporary voluntary exhaustion. It is realized that such a test does not necessarily test the "maximal" or "ultimate" physiological limits of subjects since there is a psychological limit beyond which will power cannot make them go. The will power is reflected in the oxygen debt. The standardization was in terms of pace and slope of the treadmill with endurance measured in terms of the *duration* of the run voluntarily possible with encouragement. This test, as standardized by Cureton (40, 45), is similar but not exactly the same as a hard run, such as a 600-yard run for time, in which capacity for rapid cardiovascular adjustment is tested. The reliability (r_{11}) was .90 for the treadmill run and .80 for the 600-yard run in repeat trials two days apart. The intercorrelation between the two events was .373 in 1957 and .462 in 1958.

The Sample of Boys

Except for six boys over age 14, the 57 subjects ranged from 8 to 14 years. Practice was given before the timed treadmill test to familiarize the boys with the event. Almost no apprehension or reluctance was noted, and

the competitive spirit was high. No boy became sick because of "athlete's indisposition," and no vomiting occurred, as sometimes does occur in college men.

Methods of Testing

No food was allowed for three hours before running on the treadmill. Quiet sitting, ventilation, and cardiovascular data were taken in a 30-minute period before running, a 10-minute gas sample being taken in a Douglas bag 20 minutes after the subjects rested in a chair. Warm-up was insisted upon: (a) a 1-minute treadmill walk at 3 mi/hr, (b) 5 minutes of calisthenics, (c) a 1-minute run at 5 mi/hr, (d) 8 minutes of stretching, walking, and jogging in the gym. Then the "all-out" run was taken at 7 mi/hr, 8.6 per cent grade with a "spotter" on each side of the running subject to protect against a fall.

The total gas was collected from beginning to end of the run; and then the recovery gas was collected in two other Douglas bags after the run, using a simultaneous opening and closing of valves to redirect the gas, as the Sargent mouth valve was kept in the mouth throughout the test. All sampling, analyzing, and calculating was done by procedures described in the Harvard Fatigue Laboratory Manual (97) or in Consolazio *et al.* (28).

Means, standard deviations, and intercorrelations were calculated. Then multiple regression procedures were used to calculate the *b*s and βs, in accordance with the Sewell Wright system (166), from which regression equations were made. The βs become the weighting coefficients in the

TABLE 29

Correlations of Oxygen Measures with Time of All-out Treadmill Run (7 m.p.h., 8.6 per cent grade)

Oxygen Measures	*Liters*	*l/min*	*l/min/kg*	*l/kg*
Gross oxygen intake	.921	.492	.224	.944
Net oxygen intake	.916	.508	.319	.935
Gross oxygen debt	.513	—.650	—.781	.283
Net oxygen debt	.620	—.408	—.568	.555
Total Oxygen				
Gross intake + gross debt	.860	—.353	—.708	.622
Net intake + net debt	.897	.004	—.431	.927
Oxygen Requirement				
(Gross intake + net debt) / time of run	.897	—.104	—.460	.691

NOTE.—$N = 57$.

standard score regression equations, which are used for all practical purposes without a constant in the form:

$$z_0 = \beta_1 z_1 + \beta_2 z_2 \ldots (+ k \text{ dropped}),$$

or, time in TM run in S.S. $= \beta_1$(oxygen intake capacity in l/kg) $+ \beta_2$(oxygen debt in l/min/kg).

Results of the Statistical Analysis

The results are shown in a series of tables and graphs. Table 29 shows the correlations of the dependent variables with the all-out treadmill run,

Table 30

Means, Standard Deviations, and Ranges of All-out Treadmill Tests

	Mean	*SD*	*Range*
Age in years	12.25	1.77	8 –16
Weight in kg.	46.30	11.94	24.9 –81.3
Surface area in sq. m.	1.42	.241	.92 – 1.88
Run time in min.	2.587	1.44	.75 – 6.33
Gross oxygen intake			
liters	5.30	3.98	.93 –15.19
l/min	1.88	.62	.80 – 3.55
l/min/kg	.0406	.0078	.0165– .0613
l/kg	.0176	.0666	.0205– .2640
Net oxygen intake			
liters	4.72	3.64	.734 –13.67
l/min	1.66	.59	.587 – 3.24
l/min/kg	.0360	.0085	.0119– .0562
l/kg	.0940	.0621	.0148– .2370
Gross oxygen debt			
liters	6.26	1.86	3.60 –11.42
l/min	2.92	1.52	1.05 – 7.52
l/min/kg	.0680	.0344	.0194– .1923
l/kg	.1345	.0195	.1111– .2050
Net oxygen debt			
liters	2.93	1.47	.63 – 6.62
l/min	1.29	.72	.518 – 4.29
l/min/kg	.0308	.0281	.0092– .0872
l/kg	.0606	.0236	.0134– .1201
Oxygen requirement*			
liters	8.23	5.11	1.56 –20.20
l/min	3.08	1.04	1.60 – 5.48
l/min/kg	.0698	.0156	.0456– .1193
l/kg	.1790	.1043	.0577– .3726

* (Gross intake + net debt) / time of run.

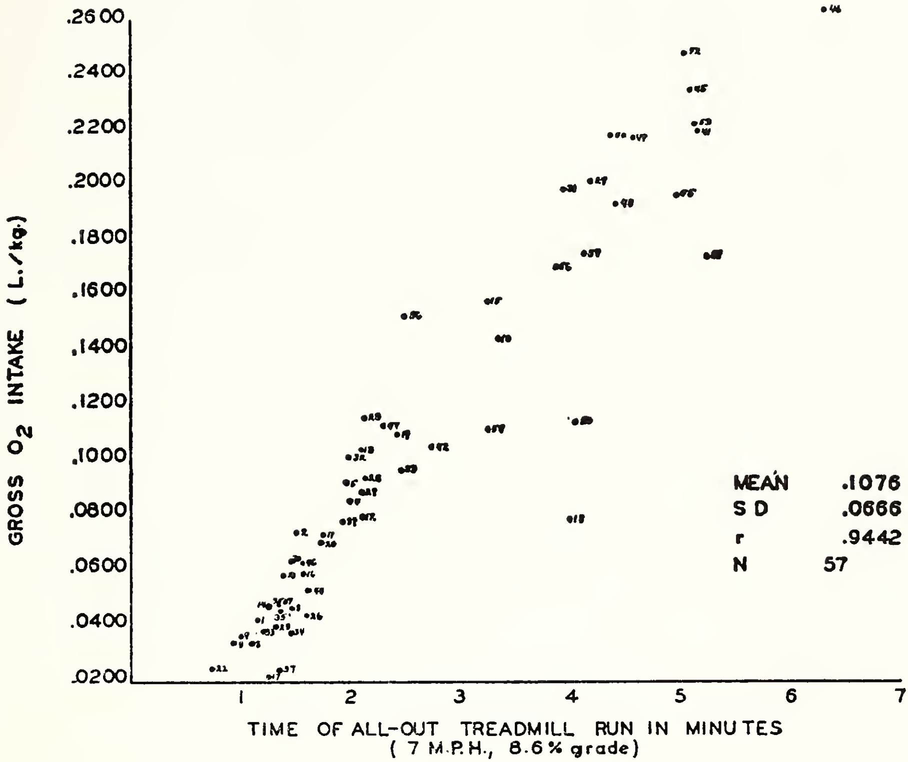


FIGURE 74—Relation of gross oxygen intake to time of all-out treadmill run.

TABLE 31

Comparisons of Equations for Prediction of Treadmill Run*

	Oxygen Intake	*Oxygen Debt*	*Multiple R*
Young men†	0.75 (gross l/kg in S.S.) 73% net proportionate contribution	—0.46 (net l/min/kg in S.S.) 27% net proportionate contribution	0.97
Young boys†	0.94 (gross l/kg in S.S.) 99.9% net proportionate contribution	—0.01 (net l/min/kg in S.S.) 0.1% net proportionate contribution	0.94 $SE_{(est)} = \pm 0.47$ minutes

* Based upon 57 cases of young boys.

† Standard score equivalent of treadmill run time (time to be obtained from table converting standard scores to seconds).

7 mi/hr/8.6 per cent grade. Table 30 shows all of the means, standard deviations, and the range for the most important variables and their units of measurement. The plotted data are shown in Figures 74 to 79.

Prediction equations were derived by the multiple regression technique combining the aerobic oxygen intake measures with the anaerobic oxygen debt results to predict the time of the treadmill run. A comparison is made with similar work on young men of college age. Tables 31 and 32 show that the young boys depend upon their aerobic oxygen relatively more than the college-age men, the latter being able to exert more will power, thus developing a higher relative oxygen debt. The most satisfactory equations combine gross oxygen intake (in l/kg) with the rate of oxygen debt (in l/min/kg). The net causal analysis (Wright's beta weight system) shows that the gross oxygen intake (l/kg) makes almost all of the percentage contribution to the run, whereas the oxygen debt makes very little in the case of the young boys but contributes relatively more in the case of the college men.

Table 32 shows a comparison of young boys ($N = 57$) with a sample of young male normals ($N = 18$), and both of these with a group of highly trained athletes ($N = 20$). In absolute figures the athletes have the highest oxygen intake, but when the weight is divided out the small boys have the largest rate of oxygen intake per kilogram of body weight. This table also shows that small boys cannot develop, or at least usually do not develop, high values of oxygen debt, as they are far below the normal young men and also the trained athletes as an average. The small boys have the smallest oxygen debt on an absolute basis or with weight divided out.

TABLE 32

Comparison of Adult Athletes and Men with Young Boys

Oxygen Measures	*Athletes* ($N=20$)	*Normal Young Men* ($N=18$)	*Young Boys* ($N=57$)
Gross Oxygen Intake			
liters	6.98	4.06	5.30
l/min	2.77	2.38	1.88
l/min/kg	.0394	.0336	.0406
l/kg	.0995	.0576	.176
Net Oxygen Debt			
liters	7.23	7.32	2.93
l/min	3.30	4.47	1.29
l/min/kg	.0470	.062	.0308
l/kg	.110	.102	.061

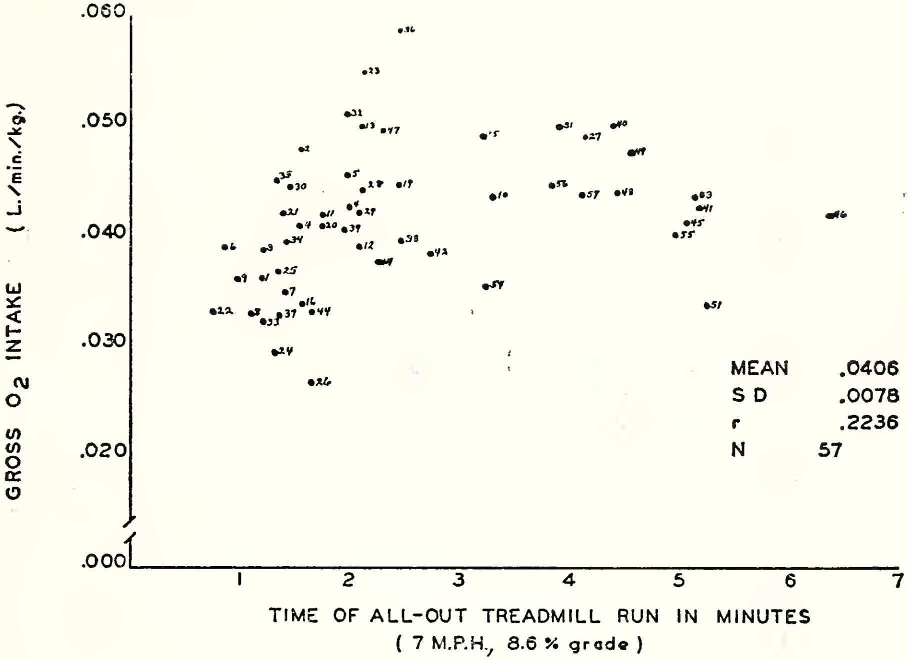


FIGURE 75—Relation of rate of gross oxygen intake to time of all-out treadmill run.

TABLE 33

Repeat Trial Data of Selected Energy, Metabolism, and Cardiovascular Measures

	Trial I (June 22)	*Trial II* (July 28)
Basal ventilation (l/10 min.)	56	64
Basal oxygen intake (l/min)	.164	.201
Maximal oxygen intake (l/min)	1.73	2.32
Maximal oxygen intake (l/min/kg)	.509	.682
Average oxygen intake (l/min)	1.36	1.76
Average oxygen intake (l/min/kg)	.400	.517
Gross oxygen debt (liters)	5.75	3.26
Net oxygen debt (liters)	1.69	.25
Treadmill run time (minutes)	2.92	6.99
Net oxygen debt (cc/min/kg)	164	10.6

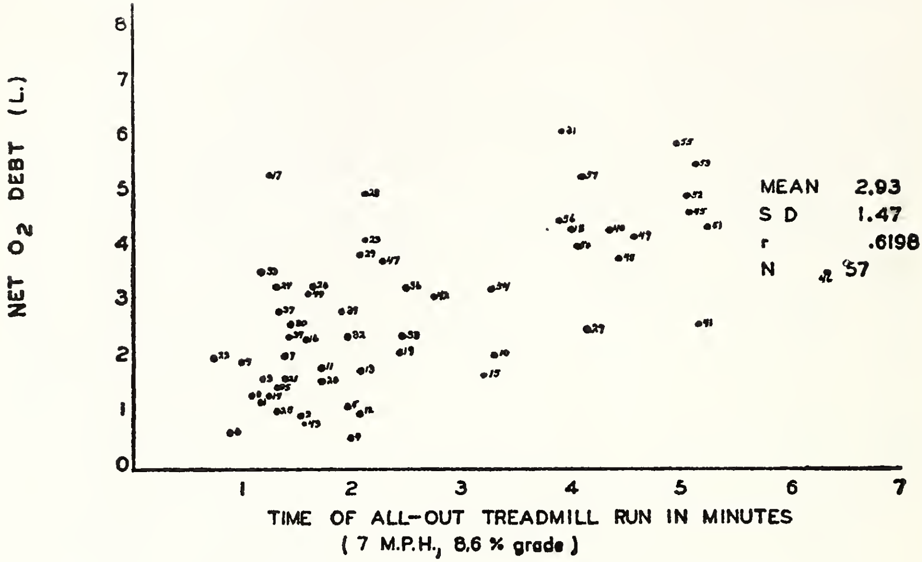


FIGURE 76—Relation of net oxygen debt to time of all-out treadmill run.

TABLE 34

Repeat Trial Data on Pulse Rate and Blood Pressure in Response to All-Out Running (raw scores)

	Trial I (June 22)	*Trial II* (July 28)
Quiet pulse rate	66	71
Terminal pulse rate	172	200
Pulse rate (2–2:30 recovery)	94	116
Pulse rate (5 min. recovery)	80	106
Pulse rate (10 min. recovery)	84	104
Pulse rate (15 min. recovery)	84	104
Blood pressure (quiet)	102/58	110/58
Blood pressure (terminal)	140/ 0†	155/ 0†
Blood pressure (2 min. recovery)	130/20	138/ 0†
Blood pressure (5 min. recovery)	110/46	122/42
Blood pressure (10 min. recovery)	106/60	116/72
Blood pressure (15 min. recovery)	106/60	114/68

† Sound heard down to zero probably due to turbulence artifacts.

Example of Unusual Responses Due to Motivation

Two 14-year-old boys in the Sports-Fitness School, W and K, ran a series of all-out treadmill runs on the motor driven treadmill at 7 mi/hr, 8.6 per cent grade. It was apparent that both were competing against the previous time of the other; and, since they knew the run times of each other, as one ran and then the other, each was motivated by the run of the other. This struggle for supremacy demonstrates the motivational factor. Their results are shown in Tables 33 and 34 for the run times and all of the physiological data collected.

With terminal systolic blood pressures of 200, 200, and 188 mm. Hg and terminal pulse rates of 192, 204, and 216 beats per minute in the three runs of subject W, it could be assumed that he was very nearly "all-out" in the physiological sense, making a run of 7:00 minutes to beat subject K's 5:00-minute run. But then subject K ran 7:00 minutes, and right afterward subject W rose to the challenge with a run of 8:05 minutes. This extra effort brought his terminal systolic blood pressure to the same level, but his terminal pulse rate rose from 192 to 204 beats per minute.

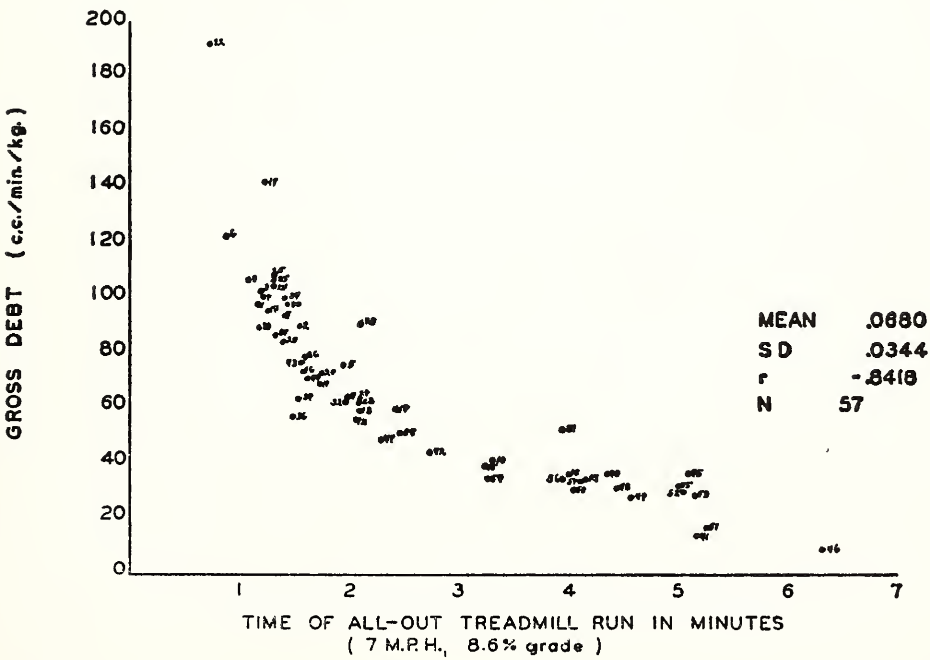


Figure 77—Relation of rate of gross oxygen debt to time of all-out treadmill run.

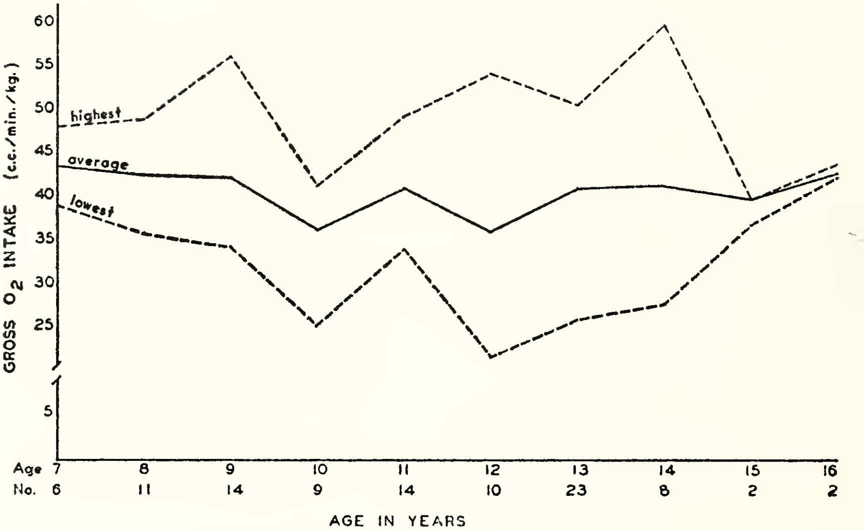


Figure 78—Relation of age to average oxygen consumption during treadmill run: Illinois data.

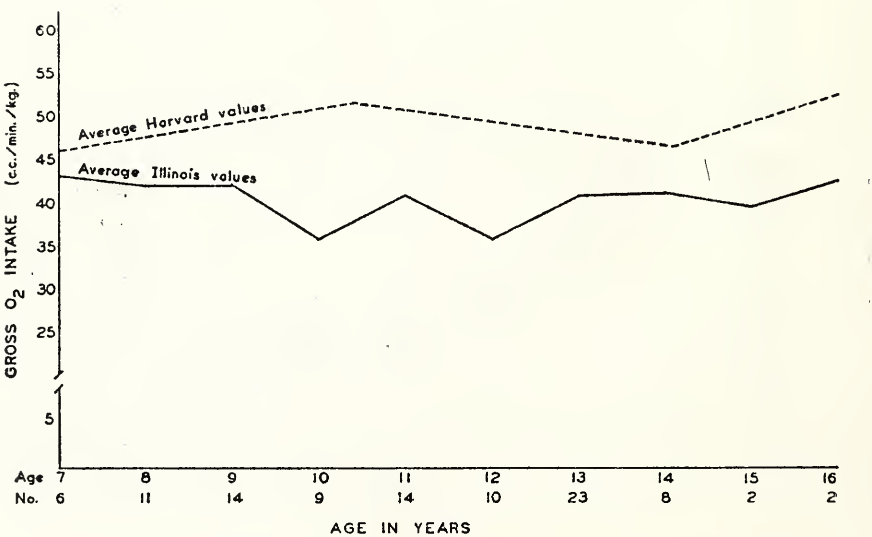


Figure 79—Relation of age to oxygen consumption during treadmill run: comparison of Illinois and Harvard data.

When subject W ran 9:00 minutes, the rivalry between the two friends was settled and K refused to continue. It is interesting that the maximal oxygen intake from several Douglas bags in series decreased from 0.633 to 0.471 l/min/kg when the run time was increased from 7:00 to 9:00 minutes for subject W. The average oxygen intake decreased from 0.551 to 0.425 l/min/kg. We have believed that this decrease in oxygen intake capacity was due to tensing up (not running ballistically enough). It is shown that the gross oxygen debt in liters increased in the longer runs of both subjects. In the case of subject W, whose run time increased from 7:00 to 8:05 to 9:00 minutes, the net oxygen debt (in liters) increased from 0.12 to 2.75 to 4.03. Similarly, subject K increased from 5:00 to 7:00 to 8:30 minutes with corresponding changes in the net oxygen debt (in liters) from 0.12 to 3.60 to 2.11. The failure of subject K to press himself to the fullest limit in the final run is paralleled by the oxygen debt change from 3.60 to 2.11 liters. Thus we have the will power exerted in this series of motivated runs reflected proportionately in the oxygen debt.

An unusual run of another young boy, only 7 years of age, designated H, weight 34 kg., is now also mentioned. He ran 2:55 on June 22, 1961, a time well above the average for his age group, at 7 mi/hr, 8.6 per cent grade. His data are shown in Tables 33 and 34. Comparable data for college men averaged 2:11 on the same test. One month later, after continuous work in the Sports-Fitness School, he ran 6:59, a feat accomplished as a rule only by trained runners. His maximum *net* oxygen intake capacity of 0.682 l/min/kg is the highest recorded in the literature for young boys of his age and rates above almost all known values at any age. The unusual aspect of the run is that the subject developed less net oxygen debt in the 6:59 run (0.11 liters) than in the initial 2:55 run (3.29 liters). Indicators such as terminal pulse rate and terminal blood pressures suggest that this subject was more fatigued on the second run of 7:00 minutes than on the first one of 3:00 minutes, yet his net oxygen debt was less on the longer run. This is consistent with data in Cureton's studies on young boys and men, indicating that either improved coordination or greater aerobic efficiency because of improved fitness could result in a lowered oxygen deficiency as shown in the oxygen debt. It is very unusual to get such large improvements in the one month which intervened between the initial and final tests.

Relative Importance of Selected Tests to Predict the Treadmill Run Time

It seems obvious from a study of the data that neuromuscular ability and oxygen intake go hand in hand and are so intertwined that running is impossible without both functioning together. The muscles must be strong enough to bear the weight easily, and especially on the treadmill must the legs be strong. The same power and spring observed in the broad jump must come into play in the treadmill run, because the body must literally

Table 35

Relative Importance of Selected Tests for Prediction of All-out Treadmill Run Time (Doroschuk, 1962)

	β Weight	β^2	*Net Contribution to Run (%)*
Age	.044	.002	0.5
Weight	.284	.081	18.2
Oxygen intake (l/min/kg)	.342	.117	26.4
Oxygen debt (l/min/kg)	.267	.072	16.2
Leg strength	.068	.005	1.1
Back strength	.159	.026	5.9
Strength/weight (sum of 4 tests)	.133	.018	4.1
Reaction time	.061	.004	0.9
Endurance hops	.113	.013	2.9
Agility run time	.191	.036	8.1
Standing broad jump	.213	.045	10.1
60-yard run time	.153	.023	5.2
Breath-holding time	.038	.001	0.2
Pulse recovery (5-min. step test)	.017	.001	0.2
		0.443	100.0

be propelled uphill on each step on the treadmill. It is not surprising, then, to see the results shown in Table 35. It is shown that muscular boys, with strong backs and legs, with capacity to jump well in the standing broad jump, run the longest on the treadmill; but they also must have good circulation as indicated in the oxygen intake capacity. They must also have the ability to bear stress as indicated in the oxygen debt, with more debt accumulating as will power is exerted more strongly to run longer. The ability of the muscular cells to use the oxygen out of the blood and to develop a stressful imbalance of dynamostasis in the blood with high blood lactate levels is also needed. The analysis shown forces the recognition of the neuromuscular factors.

Value of the Dietary Supplements for Improving Endurance

The value of the dietary supplements is shown in Table 36. The most improvement was made on crystals of wheat germ oil (Octacosanol), a derivative of wheat germ oil. In actual times also for the 600-yard run the lowest average time occurred in 1956 while the group took the crystals of wheat germ oil along with a half pint of milk, this time being 137.1 seconds, 11 S.S. improvement. The second best improvement was also made on crystals of wheat germ oil, 8 S.S., in 1957. The second best actual time was made

TABLE 36

Improvement Data from Four Years of Matched Group Training Experiments with Young Boys to Improve Endurance in 600-Yard Run With and Without Dietary Supplements (seconds)

Dietary Supplements or Placeboes	T_1 (June)	T_2 (August)	*Gain* (sec.)	*S.S. Gain*
1955—*Given basic instruction in swimming, gym, track and field, and games*				
Group A: ½ pint milk only	165.1	170.3	— 5.2	— 5
Group B: wheat germ	156.8	154.2	2.6	2
Group C: WGO capsules	166.6	161.5	5.1	6
1956—*Given basic sport instruction in four sports, plus test exercises and three 600-yard runs per day*				
Group A: cottonseed oil placeboes	156.0	149.7	6.3	4
Group B: wheat germ	156.1	146.4	9.7	7
Group C: wheat germ oil capsules	153.5	139.7	13.8	9
Group D: crystals of wheat germ oil	152.8	137.1	15.7	11
1957—*Given four periods of sports instruction plus 40 minutes non-stop endurance work*				
Group A: lecithin oil placeboes	170.0	161.0	9.0	6
Group B: wheat germ	166.0	159.0	7.0	5
Group C: wheat germ oil capsules	162.0	151.0	11.0	7
Group D: crystals of wheat germ oil	171.0	159.0	12.0	8
1958—*Given four periods of sports instruction plus 40 minutes non-stop endurance work*				
Group A: lecithin oil placeboes	151.0	149.0	2.0	2
Group B: wheat germ	150.0	151.0	— 1.0	— 1
Group C: wheat germ oil	150.0	155.0	— 5.0	— 3
Group D: crystals of wheat germ oil	151.0	149.0	2.0	2

NOTE.—All groups had the same amount of milk plus the dietary supplement.

on crystals and cottonseed oil, in a tie, 149.0 in 1958, but with improvement only 2.0 S.S. for each of these groups, 15 to 18 in each group.

The technique of these studies was to divide the whole Sports-Fitness group into three or four matched groups, on the basis of the best of two 600-yard runs on the track. Then all boys took the entire sports instruction program four days per week from 1:30 to 3:45 P.M., after which on each day a 40-minute endurance period was held. At 3:00 P.M. a brief intermission was called to feed the boys the placeboes or dietary supplements. The boys did not know what the capsules were; and, except for wheat germ

which was not camouflaged, they thought they were taking vitamins. The first year, 1955, with no dietary supplements given at all, the boys actually clocked a loss of 5 seconds while taking only milk at the intermission, while both the wheat germ oil and wheat germ groups improved 6 and 2 S.S., respectively. In 1956 the results were much the same with wheat germ oil and crystals of wheat germ oil supplements making the best improvements, but this year the lowest actual times were in the wheat germ oil group, 151.0 seconds. We concluded that cottonseed oil was not a good placebo as it seemed to have some value to boost endurance.*

Relative Value of Four Types of Endurance Programs

In 1957 the boys were divided into four matched groups by the 600-yard run, but each group worked for 40 minutes on a slightly different program. The steeplechase proved to be the best, with an average improvement from 169.0 to 151.0 seconds, 15.0 S.S. improvement; the rhythmical continuous exercise (on the spot) was next best with an improvement of 165 to 156 seconds, 5.0 S.S.; the interval training work on the track was next with improvement from 167 to 161 seconds, 3.0 S.S.; and the circuit training was poorest with an improvement from 167 to 163 seconds, 2.0 S.S.

The improvements made by these four groups range from 18 to 4 seconds. With an average time of 167 seconds for the 600-yard run, each second is equivalent to 10.77 feet. For a gain of 18 seconds this amounts to approximately 194 feet and for a gain of 2 seconds, to 21.54 feet.

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* Additional studies have matured since this monograph was originally written. C. W. Dempsey found a significant difference in favor of wheat germ oil fed as a dietary supplement (10 six-minim capsules, four days per week) in combination with an endurance training program of jogging, 30 minutes per day. *A Ballistocardiographic Investigation of Cardiac Responses of Boys to Physical Training and Wheat Germ Oil,* Ph.D. dissertation, University of Illinois, Urbana, 1963. 197 p.

Also, Whei-Chu Chen completed statistical analysis of covariance on four groups of boys, matched on the treadmill run with similar groups, to find a similar advantage in treadmill running time in data spread over four years, for the groups on wheat germ oil as a dietary supplement. *An Investigation of the Effects of Physical Training and Wheat Germ Oil on All-out Treadmill Run Times for Young Boys,* M.S. Thesis, University of Illinois, Urbana, 1964. 34 p.

IX

EFFECTS OF GYMNASTICS UPON PHYSICAL FITNESS OF BOYS

Historical Background

Until just recently there have been no objective scientific studies of the effect of gymnastics upon the physical fitness or posture of young boys. For over a hundred years the relative values of German apparatus programs versus Swedish formal (tension-held) postures and positions versus Danish free swinging, twisting, bending movements—all versus English and American games—have been argued and debated without much evaluation based upon the measured effects of such programs compared with a control group. While some studies have been made by Dr. Erling Asmussen (6) of Copenhagen, and others by Dr. Bo E. Ingelmark (76a) of Gothenburg, Sweden, these studies aim to prove a physiological principle, such as tensed versus free movement upon the circulation, and involve very few cases. These authorities recently claimed that school gymnastics are ineffective for the improvement of posture. The long-range effect, what I call the "persistent over-all effect," has not been evaluated. We are making an attempt to do that for the first time with young boys. It is important that the over-all, direct effects of the entire gymnastics course be evaluated. Johan Johansson has recently shown in a study at Fredericksburg, Denmark, that 29.3 per cent of 150 school children improved their posture in postural gymnastics courses compared to 23.1 per cent of 147 pupils taking only sports and games (*F.E.I.P. Bulletin,* 1954, 2, 61-64). It is clear that the need is for more running, swimming, skating, skiing, cycling, and rowing in addition.

Research Methods

The research methods are outlined as follows: (a) Measurement of changes in various physical fitness tests of physique, circulatory-respiratory efficiency and motor fitness, compared to a curve (test of performance) of average age versus measurement. This has the limitation of comparing each boy against an average for his particular age. For most boys this is all right, but a few endomorphs will prove to be the exception to normal improvement and development. (b) Measurement of outstanding young gymnastic performers to show how fit they are, most likely as a result of gymnastics, taken

over several years, under good instruction or by copying outstanding performers.

A critical step in the research was the making of graphs of age versus measurement, representing the normal control group, which matched closely by means but not by standard deviations with the experimental group. This method was decided upon when it was found that there were not enough boys to justify a matched two-group parallel experiment, and that it was impossible to obtain by random sample procedures a group which would match the gymnastic group in physiological age and initial gymnastic ability and which also could be matched on the various tests used. The thesis of William R. Vernon (158) along with *initial* data from the Sports-Fitness School (before any training was given) provided data for the control group graphs from 5 through 12 years, inclusive. With these graphs, as made by our statistical clerk, any one boy's test results could be plotted as to his starting point and finishing point on the graphs. When these were connected, the slope of the line could be matched visually or by comparison of tangents of the angle of inclination, and thus the rate of improvement could be compared with the control group. If a boy improved very rapidly, the cause of this improvement was studied by case-study method to determine whether the improvement was due to some particular type of somatotype, to maturation rather than exercise, or to some traceable characteristic.

One thesis, done on 107 10- to 13-year-old boys by Voisard (159), established a significant detrimental trend of endomorphy to motor performance, using the Iowa University modified Brace test, the corrected η coefficient of curvilinear correlation being .602 ± .058 between endomorphy and poor performance, while the relations to ectomorphy were positive, .479 ± .071. It is recognized that the stunts in the Iowa Brace test do not demand high strength but require balance, flexibility, agility, and coordination. The figures given prove the low relation to strength of this motor test. This is so important in interpreting the results that Voisard's findings are given in Table 37. The best motor performances were among those low in fat, mod-

TABLE 37

Iowa Brace Test Scores by Somatotype Classification (Voisard)

Good Iowa Brace Scores 9–18		*Intermediate* Iowa Brace Scores 7–8		*Poor* Iowa Brace Scores 2–6	
Endomorphs	1	Endomorphs	3	Endomorphs	13
Mesomorphs	20	Mesomorphs	3	Mesomorphs	10
Ectomorphs	25	Ectomorphs	7	Ectomorphs	6
Meso-Ecto	9	Meso-Ecto	2	Meso-Ecto	3
Medials	3	Meso-Endo	1	Endo-Ecto	1
N =	58	*N* =	16	*N* =	33

erately ectomorphic (4½ to 5½) and slightly above average in strength. The strongest boys were not usually the best in the Iowa Brace test.

Evaluation of Pond's Gymnastic School in Trampoline and Tumbling

Charles Pond, of the University of Illinois School of Physical Education and Varsity Gymnastics Coach, has offered an outstanding course for young boys in the Urbana-Champaign area. This course is 36 weeks in length, with instruction on Saturday mornings under expert instructors, covering basic tumbling movements, conditioning exercises, and trampoline practice, but no running, swimming, cycling, or endurance tests. Six theses were completed in 1953–54 which objectively evaluated the gains or losses of all the boys who finished the 36-week course in trampoline and tumbling. Only those who took both sets of tests at the beginning of the course and at the end could be used in the final comparisons. Because the course ran in three 12-week sections, some boys dropped out after one 12-week period, others after the second session; 14 out of 33 boys completed the 36 weeks. Comparative trends are shown for those who took the entire course.

The course of activities carried out over eight months was so organized that there was little "loafing" or standing around. All were kept on the move for their three-hour session. The activities consisted of forward and backward rolls, handsprings, headsprings, kip-ups, cart wheels, and, for a few, more difficult stunts. On the trampoline there was much bouncing up and down, belly flops, flips and twists, and use of the safety belt.

As a whole, there were good changes in all but one endomorph in some 16 physique measures, with appreciable reduction of fat and gain in strength and coordination. In motor fitness there was improvement of an impressive sort in chinning and dipping ability, also in trunk flexion forward but not in trunk extension backward—just opposite to what occurs in swimming. There were good gains in shoulder flexibility and in vertical jumping ability, but there were few improvements in running agility over the Illinois figure-eight course. Ankle flexibility definitely improved on the average. There were also good improvements in balance. It is very clear that the program did not develop circulatory fitness by the progressive pulse ratio test, the heartograph, or by the height of the *T* wave in the fifth CR lead (apex precordial). More endurance work might have done this, as the gymnastics program is not very sustained in the continuous running or swimming sense.

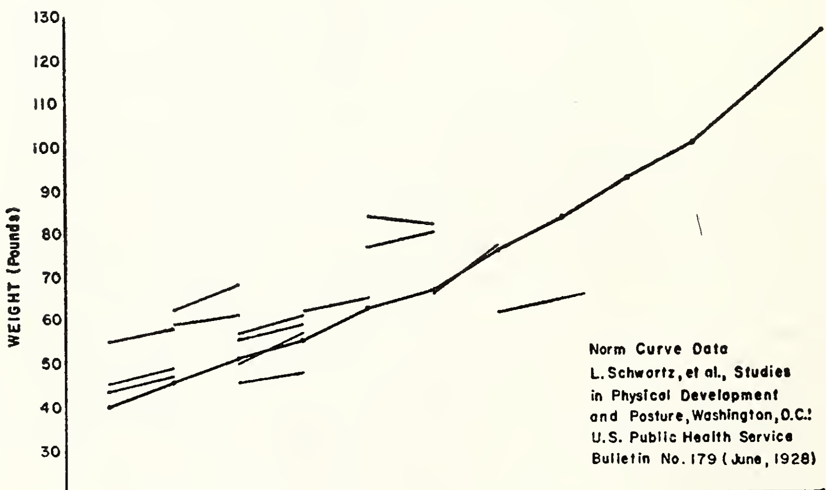
Gymnastic Stunts Used in Training

Trampoline skills included mule kicks, swivel hops, back drop, front drop, knee bounces, knee drop over forward to a seat, bounces over forward to a seat, front somersault, seat drop over backwards, seat drop turn table.

Tumbling skills included cart wheels, headstand, handstand, headspring, handspring, standing flip-flop, cart wheel roundoff-backward roll, backward roll to headstand, scale balance, long dive, elbow handstand.

Effects on Physique

The results on physique are given in the thesis by Zimmerman (167). The significant reductions of fatty tissue were noticeable in areas which were exercised vigorously. There was more than average growth in the skeletal measures of chest breadth, hip width, chest depth, and ankle girth. Associated with the changes in chest breadth and chest depth were significant changes in the flexibility of the chest, as indicated by the vital capacity changes. The vigorous jumping and springing in the tumbling and trampoline program increased the leg strength and the strength per pound of body weight. Based on the initial test, the weight residuals (actual weight over predicted weight) by the Cureton tissue symmetry analysis equation was 16.1 pounds; after training the residuals were 8.4 pounds as an average. Case-study analysis showed that fat had decreased and strength had increased in these cases. This change cannot be told with certainty from the weight residuals, as has also been shown by Wiener (163). Out of 14 boys, 8 boys of average weight moved closer to normality, with one moving further away (an endomorph); two boys under average in weight moved



AGE	5	6	7	8	9	10	11	12	13	14	15	16
MEAN	40.00	45.34	51.07	55.90	62.90	66.93	76.06	83.17	92.85	100.17	113.28	126.28
SIGMA	6.315	5.615	7.420	9.025	9.600	11.015	12.480	14.485	18.075	15.140	16.665	18.805
NUMBER	65	102	118	95	117	148	132	103	106	114	102	90
RANGE	25-64	30-59	35-89	40-84	40-99	35-109	50-119	60-144	50-159	65-144	75-159	80-174

Figure 80—Weight: pre- and post-gymnastics training changes related to norm curve (Zimmerman).

closer to normal, and two moved away somewhat (ectomorphs) (Figure 80). In height for age, three boys gained more rapidly than average and one gained more slowly. The average gain was 8 to 13.9 standard scores for the skeletal measures (Table 38). The standard scores (S.S.) show the relative

TABLE 38

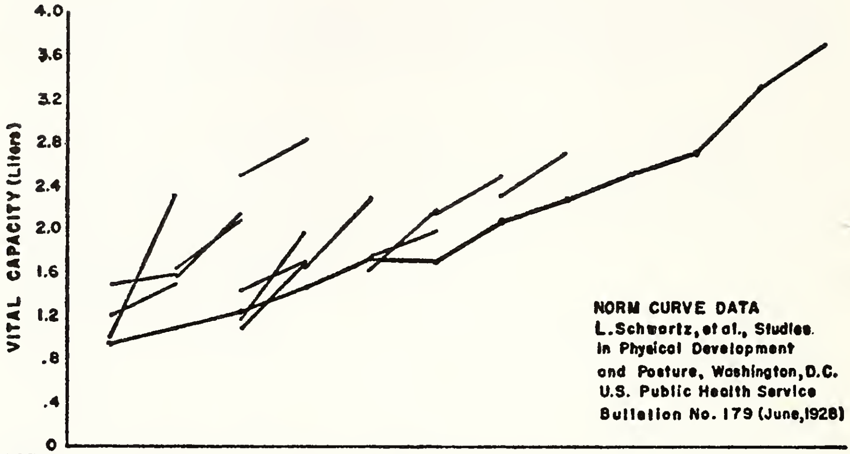
Effects of Tumbling and Trampoline Activities upon the Physiques of Young Boys (Zimmerman)

	Actual Gain (raw score)	*Standard Score Gain*	*Normal Expected Gain*
Gain in chest breadth (inches)	0.75	8.8	0.20
Gain in ankle girth (inches)	0.51	7.9	0.23
Gain in chest depth (inches)	0.74	13.9	
Gain in hip width (inches)	0.69	10.0	0.50
Gain in weight (pounds)	3.44	9.0	6.0
Gain in height (inches)	2.02	8.0	2.0
Loss in weight residual (pounds)	—7.30	—15.0	
Gluteal girth gain (inches)	0.51	1.6	1.53
Calf girth gain (inches)	0.38	3.8	0.32
Biceps girth gain (inches)	0.53	5.2	0.11
Cheek fat gain (units)	0.36	— 1.8	—0.92
Abdominal fat loss (units)	1.00	1.8	1.33
Hip fat loss (units)	0.93	2.5	0.56
Gluteal fat loss (units)	1.8	11.4	—3.46
Front thigh fat loss (units)	1.8	3.5	1.23
Rear thigh fat loss (units)	1.8	5.3	—0.95

gain, which cannot be deciphered from the raw scores. Fat was reduced most on the glutei and legs with a gain rather than a loss on the cheeks. This indicates that the parts that were used most lost fat and vice versa. Among the muscle girths the biceps gained the most. Among the skeletal measures the chest depth gained the most, which is considered a developmental measure within a limited time. The average boy gained 2.0 inches in height and 3.44 pounds in weight according to Table 38.

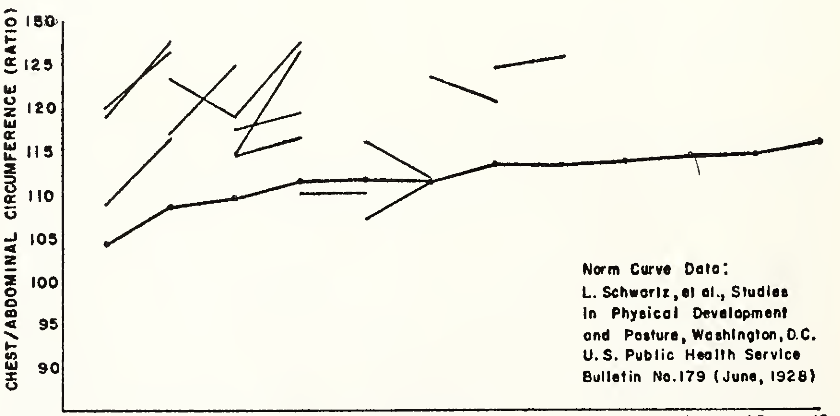
Vital capacity is considered an important measure among boys. The changes brought about in vital capacity are outstanding. One five-year-old more than doubled his vital capacity (61 to 144 cu. in.). The average gain was 31.3 cubic inches ($t = 1.99$, significant at .05 level). Figure 81 shows that 13 out of 14 boys increased their vital capacity more than the control sample did.

The ratio of chest circumference to abdominal circumference was used, and only 3 out of the 14 boys failed to improve their ratio; 8 gained more than the control sample; 3 lost relatively; and 3 remained even (Figure 82).



AGE	5	6	7	8	9	10	11	12	13	14	15	16
MEAN	.972	1.000	1.289	1.456	1.734	1.702	2.079	2.267	2.509	2.711	3.328	3.743
Sigma	.1836	.2460	.2210	.2820	.2996	.3056	.3782	.3898	.5248	.5270	.5011	.6060
NUMBER	36	90	109	95	117	148	132	103	106	114	102	90
RANGE	.6-1.3	.6-1.9	.8-.21	.8-2.7	1.0-2.5	1.2-2.7	1.2-3.3	1.4-3.7	1.2-4.3	1.8-4.1	2.0-4.7	1.8-5.5

FIGURE 81—Vital capacity: pre- and post-gymnastics training related to norm curve (Zimmerman).



AGE	5	6	7	8	9	10	11	12	13	14	15	16
MEAN	1.045	1.086	1.096	1.115	1.118	1.112	1.136	1.135	1.138	1.144	1.146	1.160
SIGMA	.399	.488	.418	.508	.644	.613	.620	.650	.534	.592	.537	.598
NUMBER	65	102	117	95	117	147	132	101	105	111	101	90
RANGE	.92-.115	.98-.123	.96-.121	.94-.125	.92-.127	.98-.131	.100-.135	.98-.131	.100-.127	.102-.131	.102-.129	.98-.129

FIGURE 82—Chest circumference over abdominal circumference: pre- and post-gymnastics training related to norm curve (Zimmerman).

One endomorphic boy, a 6 4½ 1 type, did not gain appreciably in gymnastic ability. At the start he was 22 pounds overweight; he lost 2.5 pounds and finished only 12 pounds overweight. His chest breadth gained 10 S.S., from 8.6 to 9.2 inches. His ankle girth remained the same. Chest depth increased from 6.8 to 8.3 inches, a gain of 30 S.S. His hip width stayed the same, as did his gluteal girth, calf girth, and biceps girth. His thigh girth increased from 17.5 to 18.0 inches, an increase of 4 S.S. He also gained in fat measures while everyone else was losing fat. He lost a little fat from his thighs but gained a little everywhere else. His chest circumference over abdominal circumference improved up to average. His vital capacity improved from 96.5 to 133 cubic inches, a gain of 37.5, from below average to above average.

Effects on the Feet and Jumping Ability

While there are several good studies on the measurement of the feet, including a factor analysis of the measurements (85a), there is a dearth of objective data showing that feet can be changed by exercises. For this reason the effect of the gymnastics course was evaluated by Olsson (122). The height of the internal and external malleoli were related to age, as was vertical jump; but the other measurements of ankle flexibility, the arch angles and big toe angles, were not significantly related. The gymnastics course increased the ankle flexibility of the right foot from 49.4 to 60.8 S.S.,

TABLE 39

Average Foot Measurements Before and After Gymnastics Course

	Raw Score		*Standard Score*	
	T_1	T_2	T_1	T_2
Left Foot				
Internal malleolus height (cm.)	5.84	6.24	46.6	48.3
External malleolus height (cm.)	5.23	5.80	47.0	53.6
Big toe angle (degrees)	7.4	16.6	48.3	50.3
Arch angle (degrees)	39.1	38.2	52.2	48.9
Ankle flexibility (degrees)	54.6	61.9	54.6	60.7
Right Foot				
Internal malleolus height (cm.)	5.90	6.10	47.0	48.5
External malleolus height (cm.)	5.56	5.62	52.0	50.0
Big toe angle (degrees)	15.7	17.3	53.3	48.8
Arch angle (degrees)	39.9	39.8	52.5	53.5
Ankle flexibility (degrees)	49.8	62.5	49.4	60.8
Both Feet				
Vertical jump (inches)	8.51	9.92	48.6	53.0

a gain of 11.4 S.S. The left foot increased from 54.6 to 60.7 S.S., a gain of 6.1 S.S. Twenty-two of the 28 feet tested improved during the gymnastics course with respect to ankle flexibility. In the vertical jump 9 out of 13 boys improved faster than the curve of average age versus performance; 3 subjects lost in performance. In terms of standard scores the changes were +6, +4, +2, +16, +6, −3, +3, −5, −3, +2, +11, +1, +16; one did not compete. Among the losses, the first was a medial 6-year-old and a hard worker at the gymnastic activities; the second was a medial 7-year-old, advanced in ability; the third was a medial 8-year-old. The data from Olsson's study are summarized in Table 39.

Effects on Motor Fitness

The motor fitness changes were analyzed by Matz (116). By using 11 motor test items the changes were measured from T_1 to T_2 over an 8-month interval in which the effects of the gymnastics course should be reflected. The results are briefly summarized as follows.

Chinning—improved in 71.4 per cent of the cases, with an average raw score gain of 2.39 (19 S. S.), from 1.28 to 3.67 chins.

Dipping—Improved in 78.5 per cent of the cases, with an average raw score gain of 1.50 (7 S.S.), an increase from 0.85 to 2.35 times.

Shoulder flexibility—Improved over and above the curve of age versus performance in 64.2 per cent of the cases, with an average raw score gain of 2.7 inches (24 S.S.), from 7.41 to 10.11 inches.

Trunk extension backward—Practically did not improve in anyone. The raw score gain was from 10.22 to 10.91 (4 S.S.). The gain was not statistically significant.

Agility run (Illinois figure-eight)—Improved very slightly from 25.5 to 25.36 seconds, a gain of 1 S.S. The gain was not statistically significant.

Vertical jump—Improved over and above the curve of age versus performance in 61.5 per cent of the cases, with an average raw score gain of 1.41 inches (11 S.S.), from 8.51 to 9.92 inches.

Trunk forward flexibility—Improved over and above the curve of age versus performance in 92.8 per cent of the cases, with an average raw score gain of 2.14 inches (15 S.S.), from 9.33 to 7.19 inches.

Right ankle flexibility—Improved in raw scores 12.79 degrees (18 S.S.), from 49.6 to 62.39 degrees.

Left ankle flexibility—Improved in raw scores 54.89 to 61.67 degrees, a change of 6.78 degrees (10 S.S.), but this was barely significant statistically.

Balance beam test—Improved in 46.1 per cent of the subjects tested with the raw score gain averaging 1.19 points out of 10 points (8 S.S.), an increase from 5.69 to 6.88 points.

Endurance hops—Only two subjects completed this test. One improved from 470 to 715, starting above the average for his age of 440. Another lost from 585 to 550, both above average. This test was too hard for those under

7 years of age, but at 7 years the average was 260 and this increased to 440 hops at 10 years of age and then did not change through 12 years.

Effect on Cardiovascular Condition

Based upon three studies completed in 1954 upon the same subjects, gymnastics makes no real contribution to cardiovascular condition for most of the boys tested. Wickstrom (162) carried out the progressive pulse ratio test (Cureton-Gray form), known as the PPR test. The results were complete on only 12 subjects. The average ratio for the five rates of stepping (12, 18, 24, 30, 36) was the best measure out of several which were tried. Only one boy improved the ratio (lowered it) by 0.21 point, a significant improvement. Five subjects lowered the average angle of inclination from 1 to 9 degrees but the average for the entire group was a loss from 5.2 degrees to 7.8 degrees. Four subjects decreased the "angle of break" from the 30 to 36 step rate. The other subjects made no significant changes. The group average pulse ratio increased 0.028, and the average angle of inclination increased 2.6 degrees, while the "angle of break" between the 30 and 36 step rate decreased 1.1 degrees, all insignificant changes. It is hypothesized that a more continuous rhythmical training of the Danish type would have improved this ratio significantly.

Wright (165) made a similar study on the effect of gymnastic training on the heartograph, using the quantitation techniques developed by Cureton. This study developed standard score heartograph tables for 225 young boys, 6 through 13 years, inclusive. The reliabilities were comparable with those found on adults (Table 40).

TABLE 40

Reliability of Heartograph Score (Cureton Quantitation) Before and After Training in Gymnastics (Wright)

	T_1	T_2
Systolic amplitude	.977	.976
Angle of ejection	.937	.932
Pulse rate	.979	.871
Angle of obliquity	.866	.860
Area under curve	.872	.922
Diastolic amplitude	.843	.847

In spite of good reliability, the gymnastic training program gave no indication of improving the group as an average, although one individual showed significant improvement in cardiovascular condition. Most of the youngsters deteriorated in cardiovascular fitness (Figures 83, 84). The group data are shown in Table 41.

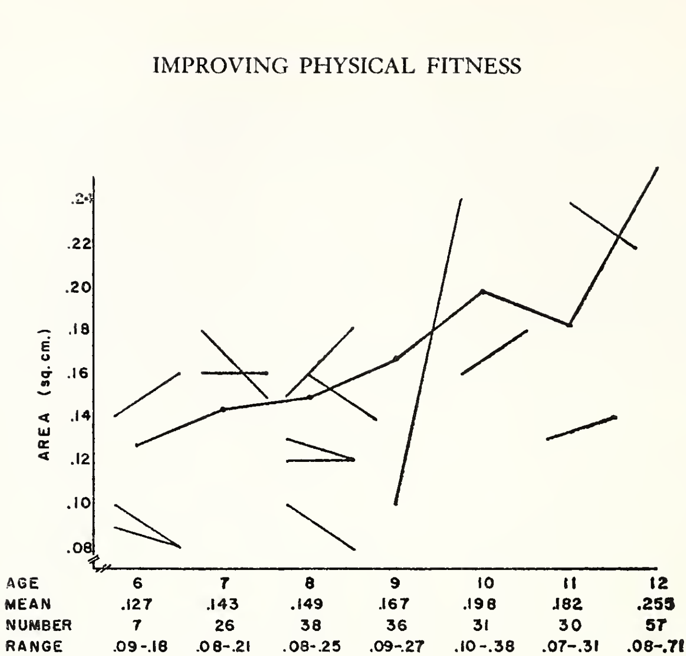


FIGURE 83—Brachial pulse wave area under the curve: pre- and post-gymnastics training changes related to norm curve (Wright).

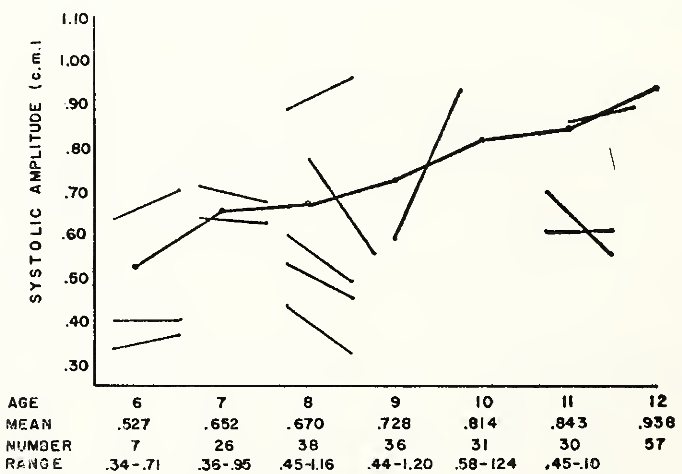


FIGURE 84—Brachial pulse wave systolic amplitude: pre- and post-gymnastics training changes related to norm curve (Wright).

TABLE 41

Average Heartograph Scores Before and After Training in Gymnastics (Wright)

	T_1	T_2	CR
Area (sq. cm.)	0.14	0.15	0.723
Area/S.A. (sq. cm. / sq. m.)	0.146	0.146	
Systolic amplitude (cm.)	0.62	0.61	0.333
Diastolic amplitude (cm.)	0.45	0.40	1.32

Still another study gave about the same conclusion. Roby (133) studied the effect of the gymnastics course upon the electrocardiogram. The *P* wave either decreased or remained the same in 10 of 12 cases, but the change was not statistically significant as an average. The *R* wave decreased in 8 out of 12 cases, but again the mean change was not significant. The *S* wave amplitude increased in 10 of the the 12 cases, increasing from 12.93 mm. to 16.29 mm. The *T* wave decreased in 8 out of 12 cases. The mean decrease was not statistically significant (Figures 85, 86, 87). The highest wave in the CR-IV or CR-V was used for the measurement. By other similar studies these changes mean that cardiovascular condition had deteriorated over the 8-month period. Some of this could have been caused by the winter season, but in other studies of an endurance type the *T* waves in the fifth lead have

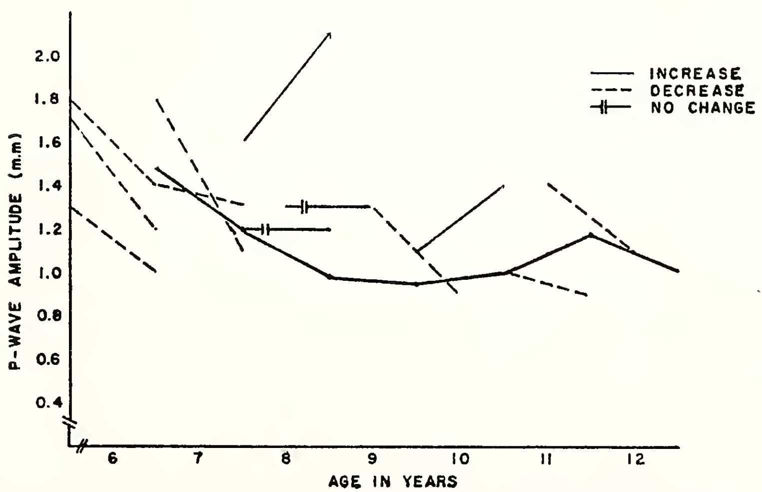


FIGURE 85—*P*-wave amplitude (ECG): pre- and post-gymnastics training changes related to norm curve (Roby).

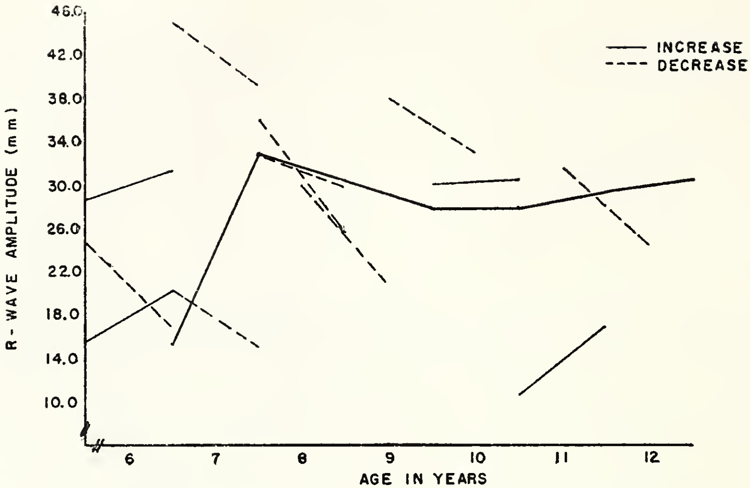


Figure 86—Highest precordial *R*-wave amplitude: pre- and post-gymnastics training changes related to norm curve (Roby).

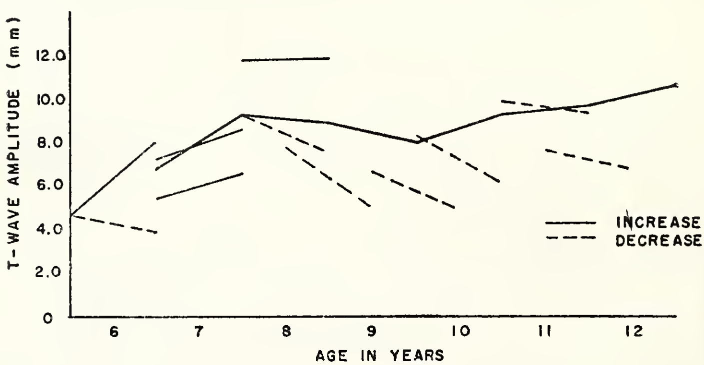


Figure 87—Highest precordial *T*-wave amplitude: pre- and post-gymnastics training changes related to norm curve (Roby).

been increased over the same period of time. The trend is similar in all three of the cardiovascular tests used. Tensing may have been the cause, as it is noticeable on "all-out" trials.

Several sets of data exist in our laboratory to show that young gymnasts of championship quality, with strength, flexibility, agility, and balance at

the 80 S.S. level or above have cardiovascular measures below average, and demonstrate poor endurance in all-out treadmill running.

Kraus-Weber Test

In the summer of 1956, 95 children from 6 to 12 years of age were tested on the Kraus-Weber test at the end of 12 weeks of instruction (50a). The group had taken instruction in gymnastics, trampoline, and tumbling for one hour per day, one to three times per week. Only nine children failed one or more of the Kraus-Weber tests, equivalent to 9.5 per cent. A comparison of several groups is revealing of the value of gymnastics exercises of this type (Table 42).

TABLE 42

Comparative Results of Several Groups of Children on Kraus-Weber Test

Groups of Children	*N*	*% Failures*
American		
Iowa	575	66.1
Kraus-Weber sample (from large eastern cities, USA)	4264	57.9
Slippery Rock, Pa.	....	49.7
Indiana	1456	45.1
Pond's Palaestrum	95	9.5
European		
Austria	678	9.5
Switzerland	1156	8.8
Italy	1036	8.0

A breakdown by age shows that the Kraus-Weber test fails to discriminate between children over nine years of age who have at least one year of basic gymnastics, tumbling, and trampoline instruction (Tables 43, 44).

TABLE 43

Comparative Results by Age on Kraus-Weber Test

Age	*Kraus-Weber*	*Indiana*	*Pond Palaestrum*
6 years	54.0	54.1	14.3
7 years	55.0	44.9	18.2
8 years	52.0	36.1	6.1
9 years	54.0	40.8	25.0
10 years	48.0	50.4	0
11 years	62.0	44.5	0
12 years	65.0	44.9	0

Table 44

Failures by Age in Flexibility and Strength in Pond's Palaestrum Group

	% Failures	
Age	*Flexibility*	*Strength*
6 years	0	14.3
7 years	•	18.2
8 years	6.1	0
9 years	16.7	16.7
10 years	0	0
11 years	0	0
12 years	0	0

Inadequacies of the Kraus-Weber Test

The Kraus-Weber test (91, 92, 93, 94, 95) fails to appraise the agility, dynamic strength, and power components of motor fitness. Other studies, especially those of Larson (101), have shown that all-around athletic ability is predicted mainly from these elements rather than from balance, flexibility, and static strength. Kraus has said that his test is of "minimal" standards. Still it is not sensible to throw to the winds all that we have learned from the construction of motor fitness tests. As a test for the medical examiner's office, is is undoubtedly suitable. But as a test of all-around motor fitness, it is inadequate.

The better testing programs are rightly based upon dynamic activity, for example, the Neilson and Cozens Achievement Scales for elementary and junior high schools, the National Red Cross and YMCA progressive aquatic tests, and the all-around Brace, or Cureton 18-Item test, the Larson tests, and others. No physical educator objects to giving the Kraus-Weber test, but there is great objection to viewing this test seriously as a real measure of fitness. It may well be used to detect a painful back. Typically, the greatest number of failures are on the flexibility and thigh flexor-abdominal sit-up events. Neither of these are highly correlated with athletic performance ability. In the administration of this Kraus-Weber test to the Pond Gymnastics and Trampoline School group, neither the strength nor flexibility items discriminate between the pupils sufficiently well to make the test valid for pupils over 9 years of age.

Phillips (126) and associates, of Indiana University, administered the Kraus-Weber Tests of Minimum Muscular Fitness to 1,456 elementary school children in Indiana. The test and the test items were found to be

highly reliable. Questions were raised about the validity of the test battery because no valid relations could be shown to dynamometer strengths; power and dynamic endurance items were missing; agility was not tested. Girls were found to be superior to boys in passing the flexibility item and in the test score as a whole. The back-strength item of holding up the chin for ten seconds with the feet held down did not discriminate sufficiently well (because not more than six of the 1,456 children failed this item), nor did the similar test with the legs raised from the floor and the chest held down. The flexibility test of touching the fingers to the floor has been questioned. The percentage of failures decreased with age so that by 11 years of age there were less than 8 per cent failures, which percentage was about the same as that reported by Kraus for European children. The inferiority of American children seemed apparent mainly in children under 11 years of age.

The Kraus-Weber test was also attacked by Fox and Atwood (61) on the basis of testing done on children in Iowa City. The flexibility failures were 56.9 per cent, higher than Kraus's 44.3 per cent. Muscular weakness accounted for 34.8 per cent, compared to 35.7 per cent in the Kraus sample, most of these in the abdominal area. More boys failed on the flexibility test than girls. These authors challenge Kraus's statement that children who fail three or more of the tests were emotionally disturbed. Using the Bakwin and Bakwin Scale of Traits, they failed to confirm this. They also objected to "failure" being in terms of any one test item, and questioned the 10-second standards in three tests as being arbitrary. It is further pointed out that several important muscle groups are not tested, such as the feet and legs, the lateral muscles, the arms and shoulders, while unjustified emphasis is put on flexibility.

A report from Newtown, Connecticut, by DeGroat (52) reflects a strong physical education program for both boys and girls, which shows what can be done when school and recreation groups work together. DeGroat is director of both programs, so he leads the children both in and out of school. For many years a competent athletic director, he gets results. In grades 7 through 11, of 158 girls tested in March, 1956, 141 passed with a perfect score all of the Kraus-Weber tests, 89.1 per cent passing, 10.9 per cent failing. Of 170 boys tested, 148 passed and 22 failed, giving 87.1 per cent passing and 12.9 per cent failing. Newtown has five periods of physical education per week required of all students in all elementary grades. Of course, the test is too easy for grades 7 to 11, where the 14- or 18-item motor tests developed at the University of Illinois would have been much better (Cureton's *Physical Fitness Workbook*, Mosby, 1947).

Hale (65), of Springfield College, made available data on boys 8 to 12 years of age, tested in a number of Massachusetts public schools. He tested 1,334 boys in three cities in the elementary schools, giving both the Rogers

P.F.I. and the Kraus-Weber tests. In three cities the percentage failures on the P.F.I. (below the national median) were: city A, 58 per cent; city B, 39 per cent; city C, 25 per cent; total group, 43 per cent. In the Kraus-Weber tests: city A, 44 per cent failures; city B, 60 per cent failures; city C, 55 per cent failures; total group, 53 per cent failures. This corresponds quite closely to the 57.9 per cent failures reported by Kraus and Weber, compared to 9.5 per cent of the European children failing the same test. Other studies, in Indiana, Iowa, and Arkansas, show 45.1, 66.1, and 49.7 per cent failures, respectively. The large percentage of failures of American children are attributed to riding everywhere in cars, extensive movie and TV habits, increasing urbanization of the United States, and the widespread use of machines of all types to do physical work.

Hale's report showed that 48 per cent of the boys in his study failed the flexibility test and that only 17 per cent failed the other five items. He showed that performance averaged better in schools which had an organized program of physical education compared to schools which did not have such a program on an organized basis. He also showed no relation by correlation between the Kraus-Weber test and the Rogers P.F.I. This calls to mind Larson's (101) depreciation of statically held test items compared to dynamic events in which the body weight is moved for speed or endurance. He showed that such events as chinning, vertical jump, dipping on bars, and dodge running were far more valid than static strength tests on dynamometers. In Hale's study we believe that the Rogers dynamometer and dynamic results are far more valid than the Kraus-Weber static events designed for use in a doctor's office.

Effect of Good versus Poor Physical Education

Whittle (161) reported on the effects of elementary school physical education upon some aspects of physical, motor, and personality development of boys 12 years of age. Contrast was made between groups of 12-year-old

Table 45

Scores on Cureton 18-Item Motor Fitness Test Comparing New Children with Children Experienced in Gymnastics

	N	*Mean*	*SD*
New boys	27	7.241	2.35
New girls	24	7.625	2.22
Experienced boys	21	10.214	2.33
Experienced girls	32	10.187	3.29

boys who participated for three years in good versus poor school programs, and who participated a lot versus a little in after-school programs. These two contrasting elementary school programs were selected by means of LaPorte's Elementary School Score Card. The comparison was made between boys meeting classification criteria for 81 boys from schools rated "poor," and 81 from schools rated "good." The results showed that the boys from the good programs exceeded the scores of the boys from the poor programs in all items except the measure of lung capacity, showing significant superiority in leg strength, back strength, vertical jump, and arm strength. Also, the boys who participated a lot in extra-school activities were significantly superior to those who participated only a little in out-of-school activities, using the Rogers P.F.I., the Rogers S.I., the Matheney-Johnson Test of Motor Educability, and the Indiana Physical Fitness Test. The "lot of after school, good program" group exceeded all others. No significant differences were shown between groups in the California Personality test. The groups compared were essentially alike in age, skeletal age, weight, height, Wetzel developmental level, and McCloy's Classification Index I.

In the fall of 1956, with the help of the Physical Fitness Research Laboratory staff, Pond tested 51 new pupils, 8 to 16 years of age, on the Cureton 18-Item Motor Fitness Test. The average percentage of failures on the items was 50 per cent (mean, 9.52; *SD,* 3.35). Then he tested 53 experienced children, 8 to 18 years of age, who had taken his course in gymnastics, tumbling, and trampoline work. The average percentage of failures was 18.5 per cent (mean, 15.33; *SD,* 2.45) (50a).

No significant difference exists between the boys and girls on the 18-Item test (Table 45). It is true that the girls did somewhat better on the flexibility

TABLE 46

Age Norms for Cureton 18-Item Motor Fitness Test

	Average Score	*N*	*Range*
7 years	5.40	10	3– 9
8 years	5.36	22	2–12
9 years	6.09	36	2–12
10 years	7.05	77	2–13
11 years	8.43	82	3–14
12 years	9.21	134	1–16
13 years	10.00	107	3–17
14 years	11.22	137	2–17
15 years	11.79	29	5–17
		634	

tests than the boys, and better on some of the balance and agility items, whereas the boys did better on the strength, power, and agility items.

As a whole, the 18-Item test gives a much more complete picture of physical fitness than the shorter and less well balanced Kraus-Weber test.

Cureton's 18-Item Motor Fitness Test

The Cureton 18-Item Motor Fitness Test (without apparatus) has been used with all ages (Figure 88). The norms are given in Table 46.

This test was given to Pond's Palaestrum group at the start of the course and was given again at the end of eight months of instruction. The results are shown comparatively in Table 47 and Figure 89. In eight months the failures were greatly reduced, as shown by the percentages of failures on the 18-Item test at the end of the course.

Effect of Age on the 18-Item Test

Age does affect the total score as well as each item on the 18-Item Motor Fitness Test, as borne out in a study of 861 subjects from 7 to 60 years of

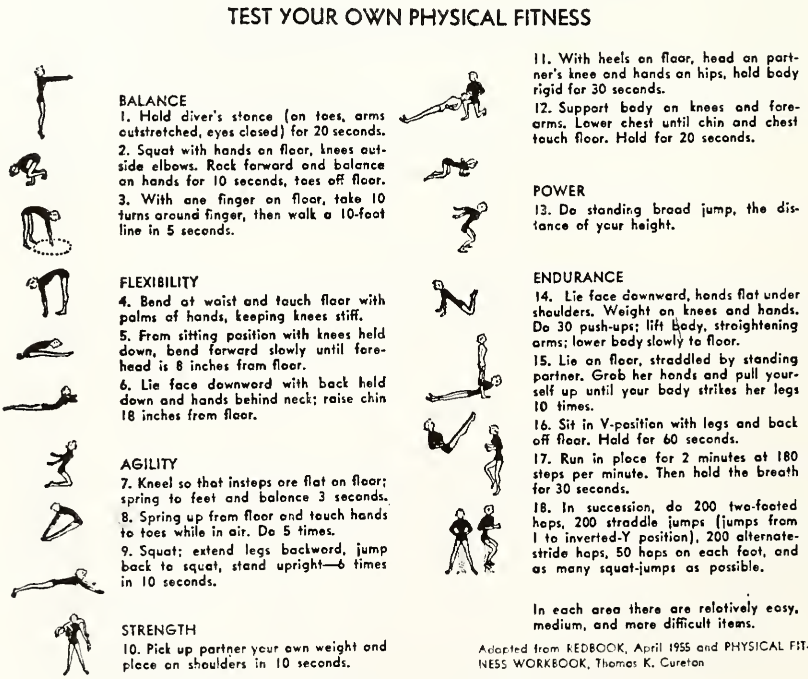


Figure 88—Cureton 18-Item Motor Fitness Test

TABLE 47

Cureton 18-Item Motor Fitness Test: Comparative Failures between New and Experienced Pupils in Pond's Gymnastics, Tumbling, and Trampoline, 1956

	Percentage of Failures		
	New Pupils ($N=51$)	*Experienced Pupils* ($N=53$)	*% Gain*
1. Balance 1	72.5	24.5	48.0
2. Balance 2	82.4	22.6	59.8
3. Balance 3	55.0	22.6	32.4
4. Flexibility 1	13.8	9.4	4.4
5. Flexibility 2	25.5	11.3	13.2
6. Flexibility 3	21.6	5.7	15.9
7. Agility 1	53.0	13.2	39.8
8. Agility 2	78.4	20.8	57.6
9. Agility 3	100.0	67.9	32.1
10. Strength 1	27.5	5.7	21.8
11. Strength 2	25.5	7.5	18.0
12. Strength 3	23.5	15.1	8.4
13. Power 1	47.0	17.0	30.0
14. Endurance 1	45.0	3.8	41.2
15. Endurance 2	33.3	5.7	27.6
16. Endurance 3	58.8	17.0	41.8
17. Endurance 4	70.6	32.1	38.5
18. Endurance 5	56.9	15.1	41.8

age. Comparison of percentage of failures can be seen in Table 48. This shows the greatest percentage of failures in the younger ages, 7 to 8 years (72.4 per cent), then somewhat less in the 9- to 12-year range (56.2 per cent), still fewer in the 13- to 14-year bracket (42.1 per cent), and fewest in the college freshman group, 16 to 25 years of age (20.5 per cent). Then there is retrogression in the middle age span, 26 to 60 years, with somewhat poorer results for women (54.1 per cent) than for men (46.4 per cent). All were normal subjects without special conditioning except what they received in school.

As a whole, the picture is rather deplorable when we realize that one really good course in gymnastics for a year would wipe out two-thirds of these failures. Since all these subjects had played games and performed dances or rhythmics, it is plain that such activities are poor in developing fitness.

TABLE 48

Cureton 18-Item Motor Fitness Test: Comparative Percentage of Failures for Various Age Groups*

	AGE 7–8 *Children* ($N=46$)	AGE 9–12 *Children* ($N=318$)	AGE 13–15 *Adolescents* ($N=192$)	AGE 16–25 *Young Men* ($N=110$)	AGE 26–60 *Men* ($N=130$)	AGE 26–60 *Women* ($N=65$)
1. Balance 1 ...	23.9	28.6	18.2	11.5	21.5	29.2
2. Balance 2 ...	95.7	72.9	71.9	27.9	49.2	81.5
3. Balance 3 ...	73.9	69.2	64.1	21.2	54.6	60.0
4. Flexibility 1 .	30.4	20.8	16.1	13.5	27.7	10.7
5. Flexibility 2 .	50.0	45.6	35.9	34.6	79.2	30.7
6. Flexibility 3 .	80.4	44.6	20.8	23.1	72.3	64.6
7. Agility 1 ...	34.8	28.0	21.9	8.7	24.6	63.1
8. Agility 2 ...	100.0	69.5	66.7	27.9	43.1	73.8
9. Agility 3 ...	100.0	95.9	94.8	24.0	62.3	70.7
10. Strength 1 ..	73.9	29.5	13.0	3.8	16.2	30.7
11. Strength 2 ..	23.9	38.7	26.6	5.8	17.7	35.4
12. Strength 3 ..	93.5	95.9	78.6	59.6	80.8	35.4
13. Power 1	89.1	38.7	31.8	8.6	51.5	86.2
14. Endurance 1	89.1	72.0	31.8	19.2	35.4	49.2
15. Endurance 2	71.7	57.5	17.7	4.8	35.4	16.9
16. Endurance 3	84.8	75.2	68.2	23.0	43.8	63.1
17. Endurance 4	100.0	69.5	46.4	40.4	70.0	84.6
18. Endurance 5	89.1	59.7	33.3	11.5	51.5	89.2
Average	72.4	56.2	42.1	20.5	46.4	54.1

* University of Illinois data.

SUMMARY AND RECOMMENDATIONS

A study of the effects of gymnastics was made on young boys in Pond's Palaestrum (Gymnastics School). None of the boys were involved in any other sports program for instruction or competition. The results show, along with other data, that the body type (somatotype) is an important factor affecting performance.

After 36 weeks of instruction in basic gymnastics by expert instructors marked improvements in physique (fat, vital capacity, chest-abdominal girth, feet) were shown, and impressive changes in motor ability were demonstrated by the tests used. Little change occurred in cardiovascular condition. It is suspected that the intermittent stunt nature (on and off) of gymnastics

does not develop circulatory fitness as well as running, swimming, cycling, and continuous rhythmical calisthenics.

The over-all generalization is, however, that a good course in gymnastics, even one two-hour period per week for 36 weeks, greatly improves the motor ability of boys. A dramatic example of this can be seen in Powell's experiment in rope skipping (Figure 49). The week-by-week improvement of his subject A illustrates the very great improvability of a growing boy.

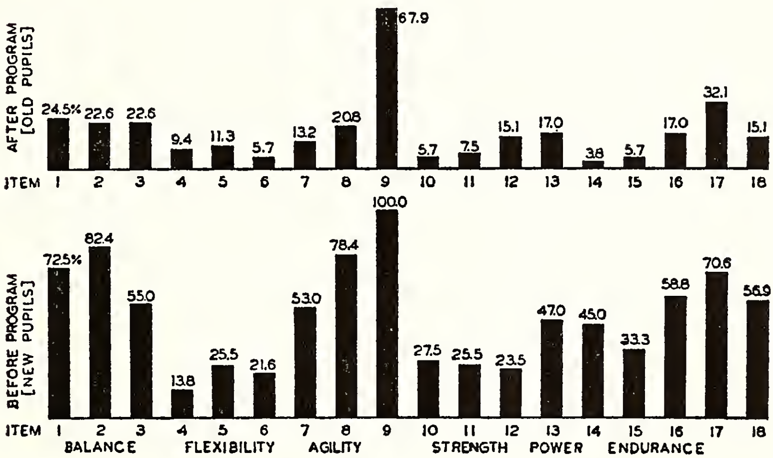


FIGURE 89—Comparison of failures on Cureton's 18-Item Motor Fitness Test: new versus old pupils in Pond's 1956 gymnastics, tumbling, and trampoline program.

X

PERSONALITY ADJUSTMENT IN RELATION TO SPORTS AND TRAINING

The belief that participation in sports and training contributes in some way to the development of desirable personality traits is widely held. This is, in fact, one of the major hypotheses underlying the inclusion of physical education in the school curriculum. Investigation of this hypothesis has, in general, followed three broad paths: (a) studies of the relations between athletes and non-athletes over a wide range of personality components; (b) studies concerning the relations between psychological characteristics and physique, motor ability, and circulatory-respiratory fitness, and (c) longitudinal studies of the changes in personality dynamics associated with camping, training, and sports.

The first of these approaches, in which the assumption has been that participation in team games and individual sports develops character, includes the largest number of studies. Along such lines, Cureton and Heusner (70) administered Cattell's 16-personality-factor questionnaire to 41 British and American former Olympic champions. The athletes varied markedly from normal subjects in four primary factors: they have greater ego strength or freedom from general neurotic tendencies (C); they are more dominant or assertive (E); they are more outgoing or less easily inhibited (H), and they show less guilt proneness or liability to worry (Q2). Cattell interpreted these primary factors as implying two second-order factors—higher extroversion and lower anxiety on the part of the champion athletes (24). Other studies, including Thune (152), representative of this approach, have shown that weight lifters tend to be strong and dominant individuals opposed to traditional team sports and that major-league baseball players are better able to adjust to occupations requiring social contact than are minor-league players, and possess more initiative (according to LaPlace [99]). Such studies provide, of course, no evidence of a causal relation between participation in sports and modifications in personality, since a preselection factor might well be operative.

The second approach has given rise to many studies directed at establishing relations between physical fitness variables and personality structure. The following examples are illustrative of the general approach. Seltzer and Gallagher (141) classified 358 adolescent boys into three groups based on interview ratings. Group A consisted of those adjudged stable in personality; group B, those who appeared well adjusted but possessed minor

flaws (excessive sensitivity, restlessness, inability to express feeling); and group C, those whose personalities seemed weak or inflexible (exhibiting insecurity, instability, lack of ability to adjust to moderate stress, lack of competitiveness, purposelessness, moodiness). The 26 boys in group C were found to be most disproportionate in physical structure (small chest girth relative to height, broad faces relative to chest width), whereas the 85 boys in group A exhibited a significant deficiency of individuals with very wide shoulders relative to their chest girth and with broad faces relative to chest width. Using the static strength of adolescent boys as the physical variable, Jones (82) demonstrated positive relations between high strength scores and social prestige and popularity, as well as noting better adjustment to home and school in the stronger boys. Feelings of inferiority and problems of social adjustment were commonly found in boys deficient in strength. Merriman (117), who analyzed personality traits (California Psychological Inventory) and motor ability (Phillips' JCR Test) in 808 high school boys, found that the upper motor-ability group differed significantly from the lower motor-ability group in the possession of more poise, ascendancy, and self-assurance.

The third approach, embracing the longitudinal study of modifications in personality, is potentially the richest in establishing precise causal relations between sports and character, but it remains largely unexplored. Using behavior frequency rating scales continually recorded over two-month periods of summer camping, Dimock (53) reported modest success in effecting changes of behavior. He cautioned, however, that desirable changes were not an inevitable outcome, and that a complex of intervening factors was involved—type of program, kind of control, group pressures and opinion, and the kind of guidance given to behavior problems. The most important single factor appeared to be that of the personal influence of the group counselor. Longitudinal observations of social interaction have been recorded in a college football squad by Trapp (154), where decreases in social distance between subgroups were noted throughout the season, and in women's physical education classes (Skubic [144]), where the volume of social interaction was doubled over a six-week period, regardless of the type of activity, when emphasis was placed on the early mutual acquaintance of students.

No more than a beginning has been made in our own attempts to unravel the linkages connecting the physiological and psychological aspects of sports and training. We do recognize, however, that every sports performance has a psychological component as well as its specific physical-fitness requirements and its relevant mechanics. Astrand (8) had something of this nature in mind when he placed "psychological variables," presumably some form of relaxation, at the head of a list of factors influencing the levels of maximal oxygen intake in "all-out" cycling and treadmill running in the laboratory. Again, Bortz (17) expresses his hypothetical human equation in terms of Energy/Diffusion plus Motivation → Achievement, Fitness, etc.

In short, he who would interpret human performance on the basis of physiological or psychological data alone seems doomed to disappointment.

At the empirical level, the psycho-physiological linkages are implicit in several approaches. In the first place, many of the physical fitness tests reflecting function in the autonomic nervous system are used also by psychologists to express changes in emotional states. These cardiovascular and respiratory tests (brachial pulse wave, pulse rate, blood pressures, breath-holding, etc.) are modified by persistent training over a period of time; and, to the extent that these measures are valid tests of emotional states, modifications in personality appear quite feasible. Second, the evidence presented by Stone and Barker (150) showing that pre- and postmenarcheal girls differ significantly in interests as measured on the Pressey Interest-Attitude Test indicates that the level of physiological development, in addition to cultural influences, is related to the maturing of attitudes. Third, in Funkenstein's (62) studies on psychiatric patients using the mecholyl test, the patients who spontaneously or under treatment showed a marked change in behavior reacted differently to mecholyl before and after treatment, leading to the conclusion that "as long as the psychological status of subjects remained constant, the physiological findings remained the same, and as long as the physiological findings remained the same, the psychological status remained constant." This interrelatedness of physiological and psychological states has long been an assumption in our interpretation of physical fitness data, each test being considered in light of both its psychological and physiological implications (Cureton [37]).

The pattern of personality traits associated with specific physical fitnesses is slowly emerging from our studies with adults and young men, although the work has not yet been fully extended to the younger age levels. Using Cattell's 16 Personality Factor test with adult males, Betz (16) found that ego strength, presumably related to maturity and emotional stability, was significantly correlated (positively) with the Schneider index and 100-yard "drop-off" swim test, whereas dominance (E+) adventurousness (H+), sophistication (N+), radicalism (Q_1+), and control of general behavior (Q_3) all possess significant *negative* correlations with the length of the "all-out" treadmill run. These last relations point to the necessity for controlling the disposition to perform "all-out" in tests of strength and endurance. The relations between these personality factors and the cardiovascular tests were studied in young men by Breen (18), who found persistent correlations between high anxiety and high systolic blood pressure, high pulse rate, and low brachial pulse wave measures of systolic amplitude, diastolic amplitude, and fatigue ratio. Wells (160) also found high anxiety, as rated in a psychiatric interview, to correlate significantly with high sitting pulse rate, low Schneider index, and low score in dips on the parallel bars; dips, chins, and the scores on the Larson chin-dip-vertical-jump test all showed significant negative correlations with a factor labeled "anxiety."

Verification of these findings, as well as the extension of the work to young boys, lies in the future. Attention has been paid, however, to the comments made by each of the instructors on the behavior of each boy in the Sports-Fitness School, involving his adjustment to the training, to the members of his group, to competition, and to the instructors themselves.

Personality Appraisals in the Sports-Fitness School

The analysis of comments for 500 boys has provided some understanding of the role that various measures of physical fitness play in the degree of adjustment attained. Sixty-four boys who gained the unanimous approval of the instructors were selected from the 500 individuals and compared with 23 boys whose behavior drew unanimous disapproval. Personality traits which were rated highly by the instructors, in order of frequency of mention, were: cooperative, gets along well with others; works hard; well-liked by others; good competitor; tries hard. That inhibition of socially unrewarding responses from the total number of responses available constitutes part of the process of socialization is indicated by the greater variety of behaviors which drew adverse comment from the instructors. Also, in order of frequency of mention here were: lacking in cooperation; aggressive (fighting in class); lazy; will not try to perform difficult stunts; does not mix with other boys; doesn't pay attention. Level of motor ability was rarely mentioned in the case of the adjusted group, but references to ability

Table 49

Physical Fitness Related to Adjustment versus Non-Adjustment

	Adjusted $N=64$		Non-Adjusted $N=23$		
Variable	*Mean*	*SD*	*Mean*	*SD*	*t*
Age in years	8.9	....	9.0	....	
Endomorphy	3.1	1.3	3.2	1.1	0.260
Mesomorphy	3.8	1.7	3.8	1.9	0.147
Ectomorphy	3.4	1.8	3.7	1.4	0.927
Reciprocal of ponderal index	13.00	0.35	13.16	0.60	1.146
Shoulder width / hip width	1.397	0.084	1.395	0.086	0.095
Total strength (standard score)	52.5	20.8	46.6	23.3	1.107
Standing broad jump (standard score)	49.2	22.8	41.0	23.1	1.427
Agility run (standard score)	54.8	15.6	44.6	20.6	2.125*
Floor push-ups (standard score)	51.3	20.2	47.5	16.8	0.863
600-yard run (standard score)	51.6	20.3	43.2	17.9	1.715
Schneider index (standard score)	47.7	21.6	49.5	17.6	0.385
Post-exercise breath-holding (st. score)	47.4	15.3	44.4	22.3	0.563

* Significant at .05 level.

and physique were not uncommon where difficulties of adjustment were present—too advanced for group; fear of water; too heavy, etc. Table 49 shows the differences in mean ratios or mean standard scores for each group.

There were no differences in the physique variables included (somatotype components, inverse ponderal index, or shoulder width / hip width), or in the circulatory-respiratory tests (Schneider index, breath-holding after exercise), but the boys who adjusted to the program were significantly higher in agility as measured by the Illinois agility run. In view of the nonsignificant *t* ratios for the other motor variables, though, it would seem that whether or not a boy adjusted to the training program depended on factors other than his physical fitness status.

Applications to Individual Cases

The utility of the preceding data lies ultimately in the manner in which it can be applied to individuals. Parents confronted with physical fitness data frequently leave the impression that, while they consider the data valuable, it hardly tells the whole story; and in this there would be considerable agreement. And yet, it is precisely at this point that gaps in our knowledge are most apparent. There is a need in physical education to build a literature of case histories comparable to those available in medicine, psychiatry, and psychology. This implies the necessity to observe as well as possible the conditions surrounding individual changes in behavior longitudinally considered, drawing at once on the observations of instructors, parents, physical data, and such quantitative psychological data as are available in the hope that a full picture of the individual thus will be obtained. Within this frame of reference, the following rough diagrams may lead to more useful and complete analyses of the future.

S.S., a Case Study

This individual (S.S.) was of medial build (3 4 3), entered the Sports-Fitness School at age 9 years and 6 months and improved approximately 20 to 30 standard scores in the motor fitness tests over his four summers of attendance at the school (Table 50). In the initial tests, this subject was average or below in all motor areas with the exception of agility (68 S.S. in the Illinois agility run) and balance (63 S.S. in progressive balance beam test). In the 18-Item motor fitness test, covering six areas of motor ability, he passed five items (45 S.S.). The second and third years were accompanied by improvements in all the motor areas except strength, which decreased 12 S.S. from the second to the third year. At this time, breath-holding after exercise and the Schneider index decreased also, which losses are probably related to the onset of pubescence as noted on the somatotype photo (age 11 years, 6 months). In the last year of our records (age 12 years,

TABLE 50

Changes over Four Years in Physical Fitness Test Scores of Case S.S.

	RS	*SS*	*RS*	*SS*	*RS*	*SS*	*RS*	*SS*
Age (years-months)	9-6	..	10-6	..	11-6	..	12-6	..
Somatotype	3 5 3	..	3 4 3	..	3 4 3	..	3 4 3½	..
Reciprocal of ponderal index	12.97	48	13.05	31	12.85	42	13.42	48
Strength/weight	3.90	40	5.29	52	3.96	40	3.27	31
Chins (number)	1.5	54	0.0	0	1.0	45	2.5	67
Dips (number)	3.0	59	0.5	15	4.0	63	7.0	81
Vertical jump (inches)	10.5	51	10.25	43	12.0	57	15.0	68
Standing broad jump (inches)	49	30	62	60	62	55	62	52
Post-exercise breath-holding (sec.)	11	43	10	38	7	30	30	83
Endurance hops (number)	300	47	725	72	735	75		
18-item motor fitness test (number)	5	45	7	50	10	60	15	80
Agility run (seconds)	21.0	68	20.2	66	20.0	65	19.5	58
Progressive bal. beam test (points/30)	18	63	24	68	30	100	30	100
Brachial pulse wave area (sq. cm.)	.24	65	.15	40	.28	73	.20	50
ECG *T* wave (mm.)	9.4	48	10.3	56	11.2	50	9.3	48

6 months) strength had decreased a further 9 S.S., although breath-holding and the Schneider index had both increased considerably (83 and 70 S.S., respectively). At this testing, subject S.S.'s motor fitness scores were, in general, 20 to 30 S.S. above the initial scores. In the 18-Item motor fitness test he passed 15 items (90 S.S.).

In his first year, this subject was rated by the instructors as poor in leadership, and fair in cooperation, interest, and perseverance. With higher levels of motor ability, he was considered in his third year as "pleasant, well-mannered, and cooperative; average in team sports; excellent in perseverance and ability in swimming; worked hard in gymnastics"; and in track and field, "doesn't possess exceptional ability but is a good competitor." In the fourth year, the instructors rated him "better than average in gymnastics," as having "fine potential in track and field," and in swimming, as being "excellent in cooperation, leadership, perseverance, and ability." He was selected as a counselor the following year, a position of responsibility which he fulfilled well. From the time of his introduction to the Sports-Fitness School, the subject showed an interest in the activities, and his parents were kindly disposed to the training program. The improvements in his motor abilities are not unusual for a boy whose interest can be maintained beyond the first year, but it is quite unusual for a boy possessing few of the qualities essential to leadership to manifest them so obviously later.

R.S., a Case Study

The problems of adjustment and lack of orderliness in motor development associated with pubescence are well illustrated in R.S. Four years of records are available, beginning at age 9 years and 1 month, at which time he showed promise of leadership that suffered a temporary lapse in the ensuing two years. R.S. was ectomesomorphic in build (2 4 5) and possessed high levels of motor ability when first tested (Table 51).

TABLE 51

Changes over Four Years in Physical Fitness Test Scores of Case R.S.

	RS	*SS*	*RS*	*SS*	*RS*	*SS*	*RS*	*SS*
Age (years-months)	9-1	..	10-1	..	11-1	..	12-1	..
Somatotype	2 4 5	..	2 4 5	..	2 4 5	..	2 4½ 5	..
Reciprocal of ponderal index	13.37	58	13.46	47	13.62	59	13.62	54
Strength/weight	3.85	39	1.78	5	4.76	50	4.11	40
Chins (number)	4.0	87	1.5	49	1.0	45	3.0	73
Dips (number)	4.0	67	4.5	69	5.0	69	3.0	52
Vertical jump (inches)	9.5	40	10.5	45	13.5	70	14.0	60
Standing broad jump (inches)	63	95	68	75	73	83	62	52
Post-exercise breath-holding (sec.)	17	58	15	50	20	63	16	50
Endurance hops (number)	270	44	430	49	730	75	732	72
18-item motor fitness test (number)	5	45	10	70	14	85	11	60
Illinois agility run (seconds)	20.0	78	19.0	78	19.0	75	19.5	58
Progressive bal. beam test (points/30)	10	40	10	33	12	33	19	53
Brachial pulse wave area (sq. cm.)	.21	60	.16	43	.17	48	.39	92
ECG *T* wave (mm.)	7.6	42	10.5	57	11.6	58	9.5	48

In the first year, all the instructors reported favorably on R.S., both as regards his ability in the various skills and the manner in which he received instruction and cooperated with other boys. One noted that "he has the potential to become a leader."

At the start of the second summer (age 10 years, 1 month), his weight had increased 8.0 pounds, but his strength had decreased and also his ability in power events. These losses are probably attributable to the preadolescent growth spurt. Although the instructors again commended R.S. for his abilities and willingness to improve them, two of them noted that he repeatedly asked questions, and one observed that his questioning attitude "upset the group considerably." His parents both noted the presence of undesirable traits ("playing to the gallery," "being excessively dominant").

At the beginning of the third summer (age 11 years, 1 month), his strength and motor abilities had improved over the previous year and were in general 15 to 20 S.S. above the initial tests. In the psychological tests

which were administered to R.S. during the third summer, he recorded an IQ of 135 on the Cattell-Cattell non-verbal test of general intelligence (25), which partly explains his disposition to question and inquire. On a test designed to evaluate anxiety (Children's Manifest Anxiety Scale), R.S. was well below average (non-anxious), and his rating on this particular trait (Factor Q_4—Low Ergic Tension versus High Ergic Tension) on the CPQ (Children's Personality Questionnaire) was similar (128). In the last test, R.S.'s profile would indicate that he is stodgy (rather than excitable and unrestrained), tough and realistic (rather than aesthetically sensitive), disposed to group action rather than individual action, confident rather than insecure, natural rather than shrewd and sophisticated, and relaxed rather than tense. A somewhat different picture was obtained from the parents, however, both of whom rated R.S. as individualistic rather than group-oriented, aesthetically sensitive rather than tough, and inclined to be tense and excitable. That behavior tends to be specific to a specific environment is well known (one is tempted to use the phrase "subcultural bias") for, although R.S.'s questionnaire answers remained relatively constant the following year, as did those of the parents, the instructors in the school described R.S. as "competitive," "a hard worker," "well liked by other boys," "polite and thoughtful," "cooperative," "mature for his age," "attentive"; there was no indication of any behavioral problems. At this time, the last year of our records (age 12 years, 1 month), the motor abilities (with the exception of chinning and balance) had shown a relative decline over the previous year, and apart from chins and endurance hops, R.S. was around average for his age. It is interesting to note that at age 12, R.S. performed 3 chins, as compared with 4 at age 9, and recorded a standing broad jump of 62 inches compared with 63 inches three years before. Strength per pound of body weight was relatively low throughout the three years, decreasing markedly at age 10 years.

It seems apparent that the adjustment problems R.S. was experiencing in the home were more prolonged than the difficulties observed during the second and third summers he participated in the summer Sports-Fitness School. In his third year in the school (age 11-1), when the parents noted that he displayed temper, was obstinate and resistant, tense and self-conscious, and was not usually polite to associates, the swimming instructor observed that R.S. was "a fine student, very active and a keen competitor; needs a challenge and enjoys hard work." The comments of instructors in other activities were less favorable. Since swimming is an activity which offers considerable opportunity for individuality of action, it seems appropriate to raise the question of whether there is a psychological readiness, as well as a physiological readiness, for specific types of activity. Most children manage to extricate themselves from the maze of mutually conflicting drives and emotions coincident with adolescence, and we normally assume that the socializing influence of team sports plays a part in this process. This may

prove to be a gross oversimplification, however, and we would probably do well to study the age changes in motivation structure in relation to the psychological dynamics peculiar to specific sports activities.

D.F., a Case Study

The third case presents no specific problems but illustrates rather well the adjustments that can be made to sports and training by a highly intelligent (IQ 149), ectomorphic boy (2 3 5) with low initial motor abilities. Entering the summer Sports-Fitness School at age 6 years and 11 months, D.F. had motor abilities generally 20 to 30 S.S. below average (Table 52).

TABLE 52

Changes over Five Years in Physical Fitness Test Scores of Case D.F.

	1957		1958		1959		1960		1961	
	RS	*SS*	*RS*	*SS*	*RS*	*SS*	*RS*	*SS*	*RS*	*SS*
Age (years-months)	6-11	..	7-11	..	8-11	..	9-11	..	10-11	..
Somatotype	2 3 4½	..	2 4 5	..	2 3 5	..	2 3 5	..	2½ 4 5	..
Reciprocal of ponderal index	12.92	46	13.31	57	13.30	57	13.13	34	13.12	47
Strength/weight	3.86	44	4.85	56	2.91	25	3.53	28	4.05	41
Chins (number)	0.0	0	1.0	45	1.5	54	1.5	49	0.5	30
Dips (number)	0.0	0	0.5	15	3.5	63	2.0	51	3.0	56
Vertical jump (inches)	6.25	30	8.5	42	7.5	16	9.5	36	13.0	66
Standing broad jump (inches)	38	23	50	50	47	20	56	48	58	45
Post-exercise breath-holding (sec.)	8	38	......		10	38	15	50	11	38
Endurance hops (number)	130	37	120	36	750	83	450	51	730	75
18-item motor fitness test (number)	3	40	4	45	15	100	11	75	13	80
Illinois agility run (seconds)	25.4	29	24.0	45	22.4	44	21.0	58	24.1	24
Progressive bal. beam test (points/30)	7	40	12	48	21	70	20	58	24	68
Brachial pulse wave area (sq. cm.)	.15	50	.10	38	.14	45	.24	62	.16	45
ECG *T* wave amplitude (mm.)	14.4	83	7.5	45	......		11.0	60	7.0	37

He was close to average in static strength (44 S.S.) but was extremely poor in dynamic strength, being unable to lift his body in either chinning or dipping. The instructors noted that he was afraid of the water, was unable to do very much in track and field, and lacked confidence in his own ability. His father reported that he was timid, oversensitive, and experienced hurt feelings frequently.

Over the four-year period with which we are concerned, D.F. improved his motor performances, especially in those movements requiring dynamic strength in the arms; and in his last summer (age 10 years, 11 months), he was able to pass 13 events in the 18-Item Motor Fitness Test (85 S.S.), as compared with 3 (40 S.S.) when first tested, and swam 14 25-yard lengths

of the pool as compared with one width. The vagaries of motor development in young boys are illustrated in D.F.'s test results from the third summer (age 8 years, 11 months). Static strength (sum of right and left grips, back and leg lift divided by body weight) declined markedly (loss of 31 S.S.), as did dynamic leg strength as reflected in the vertical jump (loss of 26 S.S.), and standing broad jump (loss of 30 S.S.). At the same time, balance, muscular endurance in the legs, and all-around motor fitness improved markedly (gains of 22, 47, and 55 S.S., respectively). Notwithstanding these irregularities in development, D.F.'s scores in his fifth summer (age 10 years, 11 months) indicated a successful adaptation to training in a boy whose parents had initially expressed concern over his inclination to avoid physical activity in favor of reading, a proclivity which led to D.F.'s being dubbed "the Little Professor" by his companions in the summer school. The final scores recorded at age 10 years and 11 months might seem a very modest achievement indeed unless viewed within the context of a comment from one of the instructors during the second summer: "Quite frankly, D.F. possesses little or no ability in track and field events. Nevertheless, it is a pleasure to instruct him because he is cooperative, receptive, and a hard competitor." By contrast, the gymnastics instructor noted that D.F., in his fifth summer, had "high aptitude" and his abilities in track and field were rated "fair."

In the Children's Personality Questionnaire (128), administered during the fourth and fifth summers, D.F.'s profile indicates that he is reserved rather than easy-going (factor A); mild rather than aggressive (factor E); aesthetically sensitive rather than tough and realistic (factor I); fond of group action (factor J); and awkward rather than sophisticated (factor N). D.F.'s father, a research professor engaged in the study of exceptional children, concurred with these ratings except in the case of factor J, where he rated his son as fastidiously individualistic rather than group-oriented.

As in the preceding case, this subject is linear, of high intelligence, though with markedly lower levels of motor achievement than R.S. Of particular interest is the fact that, in spite of his low initial abilities in motor events, D.F. adapted to the sports fitness environment more readily than R.S. The personality factors in which major differences were found, according to the CPQ scores, were factor E (D.F. submissive, R.S. dominant) and factor I (D.F. aesthetically sensitive, R.S. tough and realistic). It seems incongruous that R.S., although possessing personality traits normally considered conducive to success in sports, should experience difficulties of adjustment, and that the reverse should probably be true of D.F. Perhaps there are advantages to possessing these traits in moderate amounts. Counseling in this area will remain largely conjectural, however, until considerably more is known about the interrelations between the cultural and biological determinants of personality.

XI

SUMMARY OF FACTORS AND CONDITIONS AFFECTING IMPROVEMENT IN PHYSICAL FITNESS OF BOYS, WITH RECOMMENDATIONS

Very significant improvements have been obtained in a two-month summer day camp for boys in various motor-fitness events involving track and field, gymnastics, games, and swimming performances. These have been evaluated in the usual way of testing differences between initial test (T_1) and their second test (T_2), using the critical ratio or t test of Fisher. It was disappointing to find that the improvements in physique were so small, but it is obvious that more time was required. Improvement was usually from year to year rather than within the first two months. By plotting the improvements over several years, using boys who stayed in the program for more than one year, we have also frequently seen the relatively greater improvement in the second year compared to the first.

Fitness Improvements Due to Normal Growth and Development

Improvement naturally takes place due to time elapsing while the normal process of growth and development proceeds. A certain amount of improvement in performance would probably occur regardless of any type of physical education program. However, the concept has been present for some years that certain kinds of physical development and condition may be accelerated by imposing various amounts of training (repetitions) over and above the dosage which would be normally encountered in the daily life of the typical boy. It is conceivable that the optimum type of training, which would be neither too hard nor too easy, would help the physical development and condition, as reflected in our various tests and measurements.

Certain studies have reached inconclusive results with respect to physical exercise, or athletics, affecting physical growth. In one study Rowe (136) concluded that 13-year-old boys were retarded in growth by an unusually heavy athletic program. This study was defective in its basic design in that the athletic group had more mature boys in it than the matched group which participated only in a model physical education program. In a much better controlled study, McCraw (110) concluded that when the groups were matched on the basis of physiological maturity, there were insignificant

differences between the group gains with respect to height and weight. In other words, heavy athletics did not hurt the growth of the boys.

Actually, the athletes improved more from the seventh to ninth grade than did the non-athletes in the 50-yard dash, the standing broad jump, the vertical jump, pull-ups, push-ups, right grip, left grip, and shooting speed. The advantage was presented in raw score improvement and in percentage gain of possible gain. However, Krogman (96) takes the position that injuries among the 100,000 boys playing competitive "midget" football represent a serious angle, implying, not proving, any particular type of detriment.

It is easy to show that a group of boys will improve in motor abilities when put into the type of program which includes a well-rounded and fairly intensive program of physical education. It is much more important to show that the improvements are greater than the amount which would be expected as the normal improvement increment within the same span of time. This is harder to do and it cannot be shown with great exactness. We have used the method of plotting the data from approximately 1,000 boys spread from ages 7 to 14, using only data collected at the time of our first test on the boys, and also by eliminating any boy who had specialized instruction over and above that offered in the public schools. The assumption is that boys in the elementary school grades do not have very much instruction and practically none of it reaches the organic level that could be called "training." This group may then be used as a control group against which any individual boy may be compared with the average trend line as a basis of reference. This technique ignores the possibility that boys of different physical build will improve at different rates; at least some will not improve precisely in step with the average trend line shown in our graphs. Nevertheless, this has been used as the technique most feasible at this moment. It is true that such normal trend lines are needed for each main classification of body type (cf. Figure 85).

The continuous black line from 6.5 to 7.5 years is plotted through the means of the electrocardiograph *P* wave in the second lead. A lowering of the amplitude of the *P* wave is considered in the direction of improvement. The individual subjects are represented by the short lines with initials on them. Eight of the 12 subjects improved the *P* wave in the course of gymnastics lasting one year, with classes on Saturday mornings only. Two retrogressed and two did not change but lost with respect to the norm.

Improvements Due to Education in Physical Skills, Mainly Psychological Aspects

The steady improvement in the Schneider test from 6 to 14 years of age would seem to be related to a steady reduction in pulse rate, indicating greater nervous stability associated with experience and growing confidence. It is hard to say that this is strictly psychological, because the heart grows

in size and there is steady increase of the stroke volume of the heart, and with larger stroke there is usually reduced pulse rate. Some of this improvement is parallel to steady improvement in strength per pound of body weight, more intensive activity, and to competition. As the years pass, the accumulation of time spent in performing ordinary skills in connection with the home, as well as in childhood games and sports, steadily increases. Basically, learning a movement means ability to do the movement properly.

Motor learning cannot be separated strictly from physical growth or condition. All are going on simultaneously. It is probable that events which are controlled mainly by skill, such as target-throwing and all accuracy events (including balance), should be credited mainly to learning the coordinations. Such learning is said to be of a psychological nature and is dominated by the well-known laws of learning: (a) motivation, (b) repetition, (c) pleasant experience. Children learn to swim a given stroke if exposed a sufficient number of times to the water environment and the proper pattern of the movements. Almost all of them will learn readily enough to do a given movement within a few weeks, if exposed regularly to education in the movements required. In our opinion this holds for almost all physical skills, such as those involved in baseball, soccer, tennis, volley ball, and sports involving complicated coordinations, attitudes, and judgments. The hours of practice accumulate year by year, so improvement in these should be expected; but speed and endurance are additional qualities which improve with physiological development.

Improvements Due to Training, Mainly Physiological Aspects

Endurance especially is due to training in which there is a steady and progressive increase in the physiological load of blood placed upon the blood vessels and the heart. Such blood flow is increased in proportion to the repetition of the movements up to a certain point and as long as reasonable relaxation can be maintained. Undue tension will hinder the circulation. Such tension occurs after the rate of movement becomes non-ballistic (slow and tense).

It is hard to separate learning from training, but our concept of training is that the improved endurance is paralleled by improvement in oxygen intake and blood-flow capacity and is more than simple coordination of the movement. Since these physiological aspects are quite independent of age, as has been shown by Robinson (132) and ourselves (39 and Chap. VIII above), it is clear that such improvement in endurance is due simply to training and not to physical growth. Barry (11) investigated this problem by means of a factor analysis of a mixed matrix of test items including both physical growth measures and physical performance measures of the endurance type. The endurance measures are clearly separated from the growth measures within the age span of 7 to 11 years. Certain performances are

undoubtedly affected by a mixture of learning and cardiovascular improvements as skill is improved as well as cardiovascular condition. Events which are relatively more physiologically dominated include items like the 440-yard run and muscular endurance events like push-ups and pull-ups. For instance, the agility run is not affected very much by cardiovascular condition but by speed, skill, and body build. If any event can be done once in good form, we are apt to say that it has been learned (coordinated), whereas speed and endurance imply additional physiological capacity.

Individual versus Group Work as Related to Improvements

Our experience indicates that individualized training under the leadership of a very competent instructor is superior to improvements which occur in a group of 30 or more boys working together. This may be due to the diminished personal contact between teacher and each boy which results in a dilution of personal influence related to motivation. We have examples of such unusual individualized improvement appearing throughout this monograph (see, for example, Appendix C).

Still, extraordinary improvements have been obtained where inspirational leaders have worked with small groups of boys and have thoroughly permeated their minds with the progressive training idea. This has occurred in the studies of Powell (129) and Marsh (113). Powell trained five young boys, designated as subjects A, B, C, D, and E, to unusual levels of improvement in rope-skipping. He was a magnetic and dominant teacher who knew the activities thoroughly and demonstrated each phase of skill and did virtually every bit of work with the five boys involved. The curves of improvement from Powell's study are shown in Figure 49. They differ sharply among the five boys, due to the many factors operating.

Likewise, Marsh trained a group of young boys in bicycle riding, in which the training became progressively faster and longer. His training gains were so great that they are hardly believable but they certainly did occur. Marsh was not a particularly dominant person as a leader but in this study he used a method judged to be nearer optimal than any other method known today in the realm of endurance sports. He used the principle of interval training with progressive increases in speed and dosages, increasing both speed and distance week by week. Perhaps the extraordinary improvements obtained are due somewhat more to using the best technical method than to personal magnetism of the teacher.

But when a larger group of boys is carried through a training program for one reason or another, the average gains were found to be rather mediocre compared to the larger gains obtained with an individual or with a small squad. It is probable that many factors operate to interfere with teacher-to-pupil influence. This is certainly worsened when the teacher has poor ability, fails to demonstrate each and every event again and again, and

fails to participate in a personal leadership way. Whenever we divided the entire group of 70 to 80 boys to make four matched groups, the improvements averaged much less than when individuals or very small squads were used for similar training. It is probable that more can be done in a period; also, the personal influence of the teacher brings about additional practice at home. This is very seldom achieved unless the emphasis is very great and the impression carried vividly in the minds of the boys for hours after an instruction period.

Fatigue as Affecting the Measurement of Improvement

It is certainly true that the final series of our tests, during the last week of the eight-week summer day school, was affected somewhat by fatigue. The practical program involved a competitive "color war" in which "reds" competed against "blues." This competition culminated in a series of events settled during the last week of the program. At the same time the final tests (T_2) were given and were probably affected, at least for most boys, by the fatigue of the severe competition between sides on the previous afternoon. In order to check on this possibility we decided to retest 20 boys if we could find them still in the city after the program had ended. With rest from one to three weeks these boys gave improved cardiovascular tests in several of the more important measures, specifically the *T* wave of the electrocardiogram, the brachial pulse wave, and the Schneider index. For instance, the highest precordial *T* wave averaged 9.6 mm. at T_1 and 9.4 at T_2, eight weeks later. The post-program measurement (T_3) averaged 10.8 mm. It is certain here that the *T* wave is depressed by physical exertion of an unusual amount and does not recuperate for more than a week. Likewise, the diastolic amplitude of the sphygmogram (heartograph) was 3.3 mm. at T_1, 2.9 mm. at T_2, then rebounded to 3.7 mm. at the recheck (T_3).

It is reflected in several measures that better responses are obtained after one or two weeks of rest—to gain nutritive reserves and to remove all traces of fatigue. Thus in similar manner the Schneider index gave 6.1 (T_1), 6.6 (T_2), and 7.0 mm. (T_3); the area of the heartograph measured 0.13 (T_1), 0.20 (T_2), and 0.24 sq. cm. (T_3); the systolic amplitude of the heartograph gave 5.86 (T_1), 6.68 (T_2), and 7.33 mm. (T_3).

In a mid-year (February) check on 12 boys who had been in the Sports-Fitness school the summer before, four out of the 12 showed a reduced *T* wave at the end of the summer course, but all rebounded to higher amplitude by the February check. The 12 boys gave 7.6 (T_1), 8.6 (T_2), and 12.2 mm. (T_3); and the *R* wave gave 21.2 (T_1), 23.0 (T_2), and 31.6 (T_3).

From the rather disappointing improvement in cardiovascular condition we are certain that the real gains induced are greater than those recorded in our examples of cardiovascular changes from T_1 to T_2 covering eight

weeks of the Sports-Fitness School. This point had not been encountered in the literature, and we had to learn it "the hard way." Nevertheless, it seems clear that cardiovascular condition should be evaluated after a few days of rest rather than during the same week when severely fatiguing events are being conducted such as the treadmill run, the 600-yard run, and the "color war." Changes from one year to the next are much more definite than within the two-month period in the summer. It is interesting that Barry's (10) independent study of boys in an Australian camp came to the same conclusion.

Reductions in fat were usually not obtained with the program centered on basic instruction and sports skills (114). When the endurance aspects of the program were added to the second four years, there were consistent reductions in fat as an average for each year. The same results are seen for endurance in the 600-yard run and in cardiovascular measurements. Little change was observed in the latter until the more systematic endurance period was introduced, 30 to 40 minutes every day the instruction was held. Several patterns of endurance have resulted in improvement, but the steeplechase was best as compared to interval training on the track, muscular endurance repetitions or circuit training. All of these produced more endurance and better cardiovascular condition than performances in an assortment of games mixed with basic instruction and sports skills.

Recommendations

The pattern should now be changed from research involving a large number of test items, with tests given at the beginning and end of the two-month period, to longitudinal research involving more frequent testing on a smaller number of critical test items, perhaps on fewer boys. Training curves are needed with more points on the curve, that is, tests given every week or at least every two weeks and followed through for months, both during and after the close of the summer program.

Elementary school teachers must be shown how to lead effective exercises, of the continuous rhythmical kind, for 30 minutes without stopping. Very few of them know how, and until they know they are going to do very little.

Instruction in the basic elements of sports and games must make the main basis of physical education; but talk, rules, or intermittent action with little continuous work will not develop stamina in the youth. Even three hours per day of playing indoor and outdoor games will not do it, if we accept the four years of data from the Sports-Fitness School at the University of Illinois as essentially valid.

Activities involving muscle strength at less than half the maximal effort will not develop strength beyond trivial amounts of improvement.

The directions of the Youth Fitness Council [1] were inadequate at first in

[1] Dr. Shane MacCarthy's letter to consultants, October 14, 1957.

that stamina building activities (repetitions, dosage in duration of time, endurance activities which last five minutes or more) are completely missing from the suggestions; since 1960 they have been more adequate.

Tests should instruct as well as test in balance, flexibility, agility, strength, power, and endurance. Good tests exist, but the staff to administer such tests is usually inadequate. In most cases the elementary teachers in charge are not instructed in the details of such work, are in general untrained for it, and hence view the job as awkward and insurmountable for them until such training is secured.

In addition to basic instruction in sports, games, dances, swimming, and outdoor living, youngsters need to be trained *progressively* harder and harder, longer and longer in time duration of exercise, to develop strong hearts and circulations. As of now, there is little progression in endurance activities in any syllabus. Very few schools recognize this most important ingredient with tests or program to develop it. Such activities as rhythmic muscular (continuous) exercises, interval training in gym, pool, and on the track, circuit training, and steeplechase activities are hardly used at all. These activities should occupy 50 per cent of the time if stamina in youth is wanted. In spite of instruction in games and sports, such stamina will not be developed without such activities, even though most laymen believe that it usually will be.

In the Sports-Fitness School we have studied for several years the ways and means of developing stamina as well as skills in youth. It could not be done with casual play of games and sports. It could be done by adding a stamina drill or exercise lasting five minutes or more to each period of instruction, by repetitious running three to four times per day around a 600-yard running track, by interval training on the track, by muscular endurance exercises of the continuous type for 30 to 40 minutes; but the best of all was steeplechase for 30 to 40 minutes.

It is probable, with the small allotment of time for physical instruction and training in the schools, that after-school interest groups will have to be inaugurated on a larger scale (i.e., sports clubs with training objectives).

When we adopted the sports-fitness experimental unit for youth at the University of Illinois, beginning in 1950 for young boys, we could not allocate 50 per cent of the time to sports instruction and 50 per cent of the time to fitness (testing and motivating, advising boys and parents, evaluating progress in improving physique and endurance—circulatory-respiratory functions—and motor fitness traits and abilities) without training people to perform the testing-guidance function. We believe that we have done this well; but few of our graduates go to work in the elementary schools—they carry out the same functions in colleges, camps, YMCAs, and other places where they can get the time, equipment, and support to do this work.

Research is continuously needed in every school, college, camp, or YMCA on status, improvement, individual corrective follow-up, and the

over-all value of various programs. This is practical, empirical research. At a few places, like the Physical Fitness Research Laboratory at the University of Illinois, more profound research will be done—where, for example, it has recently been determined, or confirmed, that young boys 6 to 12 years of age have as much oxygen availability per pound of body weight as postadolescent boys, and that they have very much more than middle-aged, sedentary adults. But it takes money, personnel, and time to do such research.

Six main problems for research[2] are listed below:

1. A study of fitness of one age-grade level (eighth grade) in rural and city schools, with a fairly adequate battery of tests (physique, circulatory-respiratory, and motor ability).
2. Validity of typical physical education programs to produce fitness in the elementary schools. (This has been carried out in Champaign-Urbana over eleven years by the staff of the Physical Fitness Research Laboratory, comparing those who took the special Sports-Fitness School program with those who did not.)
3. Individual studies of improvement associated with particular programs, case by case on a longitudinal basis (see report on A.H., Appendix C).
4. A study of particular activities rather than grade to discover the improvements in fitness associated with them (e.g., swimming, skipping rope, endurance training, gymnastics, indoor games, outdoor games, track work, archery, dance, etc.).
5. Relation of improvements in muscular endurance to improvements in cardiovascular fitness.
6. Laboratory fitness testing as a means of learning about the basic concepts of fitness, that is, human fitness.

Furthermore, in conclusion, it seems that we need:

1. Training institutes in every part of the country (without complete standardization).
2. A research commission on fitness of youth, which will make periodic reports, including condensed scientific summaries.
3. Less biased and unfounded resistance to endurance training for youth merely on grounds that indoor classes in physical education are hard to conduct under the available leadership and restricted time allotments. Perhaps we need to congratulate those who find a way to do it.
4. A scientific conference on the effects of exercise (games, sports, and training) on youth.
5. Better cooperation with organizations already doing a good job within the scope of their influence (YMCA, AAU, Red Cross, Little Leagues, etc.).

[2] As recommended by the senior author (in his letter of October 10, 1957) to Dr. Shane MacCarthy.

6. More and better swimming on the elementary school and preschool level; better recognition of the non-school agencies and outdoor recreational centers who do a good deal of the work.
7. Encouragement of other laboratories like the Sports-Fitness Summer Day School at the University of Illinois; better channels through which their reports and data can be released.
8. Annual bulletins on fitness of youth by the state committees.
9. Some way to help elementary school teachers to take special fitness work in summer schools.
10. Better ways to improve the nutrition of children while in relatively hard fitness programs.

APPENDIX A

TESTS FOR PHYSICAL FITNESS AND THEIR RELIABILITY

Scope of the Physical Fitness Tests

The initial battery of tests chosen for this study includes 100 items. There is a reason for each and every item being included: either because of its intrinsic worth or because it contributes to some type of test in which several items are involved. In addition to age, there are 27 physique measures, 3 body type ratings, 12 foot measures, 3 reaction responses, a balance beam test, 3 respiratory measures, 6 strength measures, 18 motor stunts (also combined into a total battery), 22 cardiovascular items (taken from the Schneider test, electrocardiograph, and heartograph), and, in addition, an agility run, a chinning test, a dipping test on the parallel bars, a vertical jump, and a shoulder flexibility test.

In our opinion it is important that all three panels are represented, including (a) physique, (b) motor fitness (physical abilities), and (c) circulatory-respiratory measures. Specifications for these tests are not given because they are included either in *Physical Fitness Workbook* (32) or in other publications easily accessible such as *Endurance of Young Men* (49), *Physical Fitness Appraisal and Guidance* (31), *Physical Fitness of Champion Athletes* (35), or *Evaluation Materials in Health, Physical Education and Recreation* (103). One additional item may be of value in tracing the origin, standardization, procedure, and validity of the various tests and that is the *Supplement to the Research Quarterly, Physical Fitness,* 1941, 12, No. 2 (47). This entire number of the *Research Quarterly* of the American Association for Health, Physical Education and Recreation reviewed the background of about 1,000 studies in physical fitness and covers the literature pertaining thereto. New tests developed at the University of Illinois are included in the other references given.

Reliability Determinations

The various test items were tested for reliability in two different years, 1953 and 1954. These results are shown as Tables 53 and 54. In general, the physique measures have acceptable reliability with coefficients of .80 or above for retest reliability coefficients except items involving fat (pinched up); and excepted also are measures affected by respiration, like abdominal girth and chest depth. Also excepted are dimensions where considerable fat deposits, such as on hips and girth around the body at the level of the gluteals. The center of gravity test, using platform scales and a balance beam, was found to be unreliable (.285) for use with very young boys. It was considerably harder to judge ectomorphy (.538 and .647) than it was to rate endomorphy (.853 and .880) or mesomorphy (.780 and .740). In general, the foot measures were quite satisfactory except for the big toe angles of right (.583 and .500) and left feet (.686 and .623), and also ankle flexibility, although all of these measures have a reliability of .50 or better; yet none reached .80.

TABLE 53

Reliability from Retesting (Summer, 1953 and 1954)

	1954			1953
	r	*N*	*PE*	*r*
Physique Measures				
Weight	.990	75	.0031	.966
Chest breadth	.890	74	.0148	.919
Ankle girth	.907	74	.0148	.891
Chest depth	.880	75	.0176	.777
Hip width	.955	75	.0061	.662
Height	.994	75	.0031	.984
Knee width	.891	75	.0148	.934
Gluteal girth	.982	74	.0031	.937
Calf girth	.898	75	.0148	.959
Biceps girth	.902	75	.0148	.915
Thigh girth	.966	75	.0061	.871
Fat on cheeks	.885	75	.0176	.750
Fat on abdomen	.962	75	.0061	.871
Fat on hips	.928	75	.0120	.890
Fat on gluteals	.750	75	.0329	.611
Fat on front thigh	.844	75	.0229	.804
Fat on rear thigh	.819	75	.0255	.743
Total fat	.915	75	.0120	...
Shoulder width	.918	75	.0120	.838
Chest girth, normal	.946	75	.0091	.901
Chest girth, deflated	.960	75	.0061	.914
Chest girth, inflated	.970	75	.0031	.905
Arm span	.912	73	.0120	.915
Abdominal girth	.966	75	.0061	.734
Center of gravity (front)	.990	75	.0031	.285
Center of gravity (rear)	.984	75	.0031	.285
Body Type Number				
Endomorphy	.880	73	.0176	.853
Mesomorphy	.740	73	.0352	.780
Ectomorphy	...	..	....	...
Foot Measures				
Arch angle, right foot	.919	75	.0120	.946
Arch angle, left foot	.918	75	.0120	.954
Big toe angle, right foot	.582	75	.0517	.583
Big toe angle, left foot	.623	75	.0479	.686
Scaphoid deviation, right foot	.732	75	.0342	.787
Scaphoid deviation, left foot	.717	75	.0375	.807

(*table continued on next page*)

TABLE 53 (*continued*)

Reliability from Retesting (Summer, 1953 and 1954)

	1954			1953
	r	*N*	*PE*	*r*
Foot Measures (continued)				
External malleolus height, right foot	.737	75	.0352	...
External malleolus height, left foot	.872	75	.0176	...
Internal malleolus height, right foot	.895	75	.0148	.958
Internal malleolus height, left foot	.867	75	.0203	.953
Ankle flexibility, right foot	.500	75	.0584	...
Ankle flexibility, left foot	.559	75	.0535	...
Reaction Time				
Visual	.656	64	.0472	.745
Auditory	.713	64	.0403	.679
Visual and auditory	.760	63	.0353	.723
Balance Beam				
One trial only	.588	69	.0535	...
Total score, 2 trials	...	..	....	.695
Expiratory blow (maximum)	.737	72	.0365	.743
Flack breath-holding	.692	70	.0411	...
Strength				
Right hand	.921	72	.0124	.904
Left hand	.907	72	.0153	.882
Back	.910	72	.0124	.825
Leg	.828	72	.0264	.819
Total strength	.944	72	.0094	.902
Total strength / body weight	.756	72	.0341	.752
*18-Item Motor Test**				
Diver's stance (limit 20 sec.)	.264	74	.0726	...
Squat stand (limit 10 sec.)	.564	72	.0553	...
Dizziness recovery	.253	69	.0752	...
Floor touch (almost 50% scored 0-0)	.790	71	.0290	...
Trunk forward flexion	.871	71	.0182	...
Trunk extension backward	.767	74	.0329	...
Kneeling jump (pass or fail: tetrachoric $r=.862$)	...	73	....	...
Jack spring (pass or fail: tetrachoric $r=.799$)	...	..	....	...
Agility exercise	.670	73	.0419	...
Man lift	.378	59	.0745	...
Stick body (limit 30 sec.; about 86% scored 30-30)	...	..	....	...
Extended press-ups (too few did this item)	...	..	....	...
Standing broad jump	.895	74	.0148	...
Floor push-ups	.702	73	.0397	...

(*table continued on next page*)

TABLE 53 (*continued*)

Reliability from Retesting (Summer, 1953 and 1954)

	1954			1953
	r	*N*	*PE*	*r*
18-Item Motor Test (continued)				
Straddle chins (limit 20)	.682	73	.0419	. .
V-sit	.620	73	.0479	. . .
Breath-holding (after run in place)	.476	71	.0620	. . .
Endurance hops	.550	71	.0553	. . .
Total score	.865	74	.0229	.748
Motor Tests				
Agility run	.769	73	.0329	.576
Chins	.704	74	.0397	.860
Vertical jump	.779	74	.0305	.781
Dips	.851	75	.0203	.766
Shoulder flexibility	.706	75	.0397	. . .
Schneider Test				
Pulse rate, lying	.599	73	.0498	.663
Systolic blood pressure, lying	.727	73	.0375	.702
Diastolic blood pressure, lying, 5th phase	.333	72	.0713	.517
Pulse rate, standing	.364	73	.0678	.415
Systolic blood pressure, standing	.650	73	.0440	.602
Diastolic blood pressure, standing, 5th phase	.467	72	.0636	.188
Pulse rate after exercise	.420	73	.0641	.433
Recovery time	.199	73	.0748	.389
Total score	.373	73	.0666	.522
Electrocardiogram				
R-wave amplitude	.750	73	.0329	.781
T-wave amplitude	.765	73	.0329	.745
QRS time	.692	73	.0397	.519
Heartometer				
Area	.631	74	.0460	.296
Angle of obliquity	.468	74	.0614	.243
Systolic amplitude	.765	74	.0329	.665
Diastolic amplitude	.511	74	.0568	.328
Cycle time	.570	74	.0517	.353
Systolic blood pressure	.141	49	.0935	.371
Diastolic blood pressure	.254	51	.0889	.391
Pulse pressure	.431	48	.0769	.280
Pulse rate	.700	74	.0397	.574
Angle of ejection	.477	74	.0599	.502

* No comparison made with reliabilities for 1953 because of differences in scoring on many items. (a) Broad jump passing: height + 1 foot; (b) broad jump passing: height.

TABLE 54

Reliability from Retesting (Boys, Summer, 1953)

	r	*N*	*PE*
Physique Measures (Mirfield)			
Height	.984	52	.0038
Weight	.966	53	.0071
Calf girth	.959	53	.0071
Gluteal girth	.937	54	.0106
Knee width	.934	51	.0111
Chest breadth	.919	54	.0140
Biceps girth	.915	54	.0140
Arm span	.915	51	.0147
Chest girth, deflated	.914	54	.0140
Chest girth, inflated	.905	53	.0173
Chest girth, normal	.901	54	.0173
Ankle girth	.891	54	.0173
Fat on hips	.890	54	.0189
Thigh girth	.874	54	.0205
Fat on abdomen	.981	54	.0205
Elbow width	.846	50	.0281
Shoulder width	.838	53	.0268
Fat on front thighs	.804	54	.0327
Chest depth	.777	54	.0356
Fat on cheeks	.750	54	.0397
Fat on rear thigh	.743	54	.0411
Abdominal girth	.734	54	.0411
Hip width	.662	54	.0513
Fat on gluteals	.611	48	.0587
Center of gravity	.285	46	.0927
Body Type Number (Mirfield)			
Endomorphy, Component I	.853	30	.0321
Mesomorphy, Component III	.780	30	.0482
Ectomorphy, Component II	.538	30	.0872
Foot Measures (Wells)			
Internal malleolus height, right foot	.958	61	.0068
Arch angle, left foot	.954	61	.0068
Internal malleolus height, left foot	.953	61	.0068
Arch angle, right foot	.946	61	.0101
Scaphoid deviation, left foot	.807	61	.0313
Scaphoid deviation, right foot	.787	61	.0341
Big toe angle, left foot	.686	61	.0468
Big toe angle, right foot	.583	61	.0578

(*table continued on next page*)

TABLE 54 (*continued*)

Reliability from Retesting (Boys, Summer, 1953)

	r	*N*	*PE*
Reaction Time (Moore)			
Visual	.745	42	.0482
Auditory	.679	42	.0544
Visual and auditory	.723	42	.0514
Balance Beam (Moore)			
Total score on two trials	.695	42	.0544
Trial 1	.516	44	.0734
Trial 2	.446	44	.0811
18-Item Motor Test (Moore)			
Floor touch	.862	47	.0262
Standing broad jump	.758	45	.0425
Total score	.748	47	.0455
Floor push-up	.741	47	.0455
Trunk flexion	.723	45	.0484
Trunk extension	.652	46	.0568
Endurance hops	.612	47	.0619
V-sit	.574	47	.0690
Squat stand	.564	47	.0690
Kneeling jump	.554	47	.0690
Jack spring	.550	47	.0701
Agility exercise	.538	46	.0712
Diver's stance	.433	47	.0811
Man lift	.416	46	.0828
Breath-holding after run in place	.392	46	.0845
Straddle chins	.377	47	.0860
Stick body	.373	47	.0860
Dizziness recovery	.354	47	.0875
Extended press-up (insufficient data)	...	47	....
Total score	.837	47	.0260
Strength (Moore)			
Right hand	.904	46	.0191
Total	.902	46	.0191
Left hand	.882	46	.0227
Back	.825	46	.0329
Leg	.819	46	.0329
Total strength / weight	.752	46	.0425
Motor Tests (Moore)			
Chins	.860	45	.0262
Vertical jump	.781	45	.0394
Dips	.766	45	.0425
Agility run	.576	41	.0708

(*table continued on next page*)

TABLE 54 (*continued*)

Reliability from Retesting (Boys, Summer, 1953)

	r	*N*	*PE*
Schneider Test (Redden)			
Systolic blood pressure, lying	.702	56	.0464
Pulse rate, lying	.663	56	.0513
Systolic blood pressure, standing	.602	56	.0582
Total score	.522	56	.0664
Diastolic blood pressure, lying (5th phase)	.517	56	.0664
Pulse rate, immediately after exercise	.433	56	.0733
Pulse rate, standing	.415	56	.0749
Recovery time	.389	56	.0778
Diastolic blood pressure, lying (4th phase)	.318	44	.0903
Diastolic blood pressure, standing (5th phase)	.188	56	.0880
Diastolic blood pressure, standing (4th phase)	.033	45	.1004
Electrocardiogram (Redden)			
R-wave amplitude	.781	53	.0356
T-wave amplitude	.745	57	.0411
QRS	.519	57	.0664
Heartometer (Gray)			
Diastolic surge	.752	57	.0384
Systolic amplitude	.665	57	.0513
Pulse rate	.574	57	.0604
Fatigue ratio	.546	56	.0644
Angle of ejection	.502	57	.0682
Dicrotic notch amplitude	.434	57	.0733
Diastolic blood pressure	.391	57	.0764
Diastolic time	.391	57	.0764
Systolic blood pressure	.371	57	.0778
Cycle time	.353	57	.0792
Diastolic amplitude	.328	57	.0816
Area	.296	56	.0828
Rest/work ratio	.296	57	.0828
Pulse pressure	.280	57	.0838
Obliquity angle	.243	57	.0857
Systolic time	.103	57	.0900
Breath-Holding (Gray)			
Before exercise	.662	53	.0513
After exercise	.594	54	.0582
Expiratory force (Gray)	.743	54	.0411

NOTE.—Vital capacity was not calculated because data were not normed for young boys. Progressive pulse ratio and treadmill run for time were not included in the reliability program but were obtained in related work.

Reaction in terms of response time give reliability coefficients ranging from .656 to .760, using the Illinois vertical jump reaction time test.

Allowing one trial on the balance beam for each of the seven stunts included yielded reliabilities from .446 to .516, but when two trials were allowed on each stunt the reliability increased to .695, and with three trials to .800.

Items involving will power, such as the expiratory blow on the Flack U-tube, breath-holding, and voluntary endurance performances, are all slightly below the acceptable standard of .80. Will power varies a great deal among young boys, and the main variation was in the very young ages. On the other hand, strength, as tested by dynamometers, yielded better reliability coefficients for both years than the corresponding voluntary will-power efforts of strength, such as chinning, V-sit, and endurance hops, gave.

The electrocardiograph deflections gave coefficients slightly below the level of .80 with the two best being .781 for the amplitude of the *R* wave and .765 for the amplitude of the *T* wave. In both instances the highest wave was accepted as the best measure.

The 18-item motor test as a total score for the entire test had a reliability of .748 the first year and .865 for the second year.

It is necessary to report, unfortunately, that the Schneider test was too unreliable, with the reliability coefficient being .522 for the first year and .373 for the second year. The systolic blood pressure lying and standing was fairly acceptable, from .602 to .727, but the pulse rates lying, standing, and after the five-step exercise, are too low to be acceptable; and the time for the pulse rate to recover was the poorest of all. By comparison, the electrocardiograph deflections and heartograph measures were more reliable for the amplitude or area of these measures.

Causes of Unreliability

The Schneider test was taken as the first test after arriving in the laboratory. Some of the boys had to hurry to make the time appointment, and the principal variations are attributable to tension and anxiety among those who were under pressure. They also had to walk up three flights of stairs to get to the research laboratory before they could be tested. Some were tested right away, and others were tested later. Reliability could have been improved by having them all lie down for at least half an hour before they took their tests. The shortest wait was approximately 5 minutes; and they did not all wait the same length of time, this ranging from 5 minutes to 40 minutes. It was impossible to have enough examiners, facilities, or instruments to put them on an identical time schedule.

Certain items, such as the balance beam, were improved in reliability by giving the best of two or three trials rather than judging on the basis of one trial.

It is interesting that dynamometer tests are more reliable than the dynamic (moving) ways of testing strength, by pushing up or pulling up the body weight. The push-up item is notoriously hard to control because of the sag in the mid-section. Strict administration of the tests helps to make slightly better reliability. The fact that too many tests were given in one morning is a bit unfortunate because the reliabilities could have been better with fewer items more carefully administered. Nevertheless, except for a few items, the reliability of about four-fifths of the tests is quite acceptable for this type of work. It can be said that the testing was better supervised and more conscientiously conducted than is usually the case in physical education.

From the experience of giving tests to boys 7 to 14 years of age we have concluded that the following suggestions should be very carefully considered in work of this kind in order to secure reliability as high as can reasonably be obtained.

1. Preliminary rest should be allowed before any item which involves exertion.

2. Every possible measure should be taken to allay apprehension on the part of youngsters who are afraid of "medical whitecoats," technical instruments, nose clips,[1] a fast-running treadmill, and stunts done on high bars or apparatus located more than two feet above the ground.

3. Careful instruction is needed on each item to indicate how good standards can best be obtained.

4. Nervousness can be reduced by reading funny books while awaiting a test.

5. A demonstration of every test should precede any performance effort.

6. Constant motivation and encouragement should be given by the testing personnel in charge.

7. Leadership should be provided for every run or similar exercise taken by a group.

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[1] Clips should not be too tight, and a few minutes practice breathing should be given.

APPENDIX B

STANDARD SCORE TABLES OF PHYSICAL FITNESS TESTS AND MEASUREMENTS FOR PREADOLESCENT BOYS

The tables given in the next 25 pages include the age span from 7 to 13 years, for almost all of the tables. There is a little irregularity due to the nature of the event and also due to the fact that there were relatively few 14-year-old boys. The tables are numbered 55 through 109, and are grouped in the order in which they are usually used: first, *physique aspects;* second, *motor fitness aspects;* and third, *cardiovascular-respiratory aspects.* This is the order in which a boy's test folder is usually worked over at the time of the parental interview.

The number of cases in each age class varies, of course, but the number is shown at the bottom of each column along with the *mean* and *standard deviation* derived by the usual statistical techniques. Although each distribution was plotted, only the trend of the means is given in the monograph as plotted against age, shown throughout the monograph as *figures.* In some cases, due to skewness and associated curvilinearity, smoothing was resorted to in order to make a useable table. The range from 0 to 100 *standard scores* represents the over-all spread of the table within each age class. The *mean* was first determined and located at the 50 S.S. line. Each increment of 5 S.S. then was computed from $6SD/100 \times 5$. This was added successively to the mean, and also subtracted from the mean, to obtain the values at each of the $5SS$ steps in the table.

In working up an individual folder, the test is usually scored in raw scores and entered in *black.* The corresponding S.S. values are looked up in the tables and entered in *red.* The red S.S. values are put in parentheses. This prevents confusion in using the test folders.

Table 55

Height (inches)

Age in years: 7	8	9	10	11	12	13	SS
57.2	59.3	61.1	63.9	66.1	68.8	72.4	100
56.5	58.6	60.4	63.1	65.3	68.1	71.3	95
55.8	57.9	59.7	62.4	64.5	67.4	70.3	90
55.1	57.2	59.0	61.6	63.7	66.7	69.2	85
54.4	56.5	58.3	60.8	62.9	66.0	68.2	80
53.7	55.8	57.6	60.1	62.1	65.3	67.1	75
53.0	55.1	56.9	59.3	61.3	64.6	66.1	70
52.3	54.4	56.2	58.6	60.5	63.9	65.0	65
51.6	53.7	55.5	57.8	59.7	63.2	64.0	60
50.9	53.0	54.8	57.1	58.9	62.5	62.9	55
50.2	52.3	54.1	56.3	58.1	61.8	61.9	50
49.5	51.6	53.4	55.6	57.3	61.1	60.8	45
48.8	50.9	52.7	54.8	56.5	60.4	59.8	40
48.1	50.2	52.0	54.1	55.7	59.7	58.7	35
47.4	49.5	51.3	53.3	54.9	59.0	57.7	30
46.7	48.8	50.6	52.6	54.1	58.3	56.6	25
46.0	48.1	49.9	51.8	53.3	57.6	55.6	20
45.3	47.4	49.2	51.1	52.5	56.9	54.5	15
44.6	46.7	48.5	50.3	51.7	56.2	53.5	10
43.9	46.0	47.8	49.6	50.9	55.5	52.4	5
43.2	45.3	47.1	48.8	50.1	54.8	51.4	0
50.2	52.3	54.1	56.3	58.1	61.8	61.9	*M*
63	85	72	55	52	30	21	*N*
2.48	2.33	2.24	2.51	2.76	2.24	3.51	σ

Table 56

Weight (pounds)

Age in years: 7	8	9	10	11	12	13	SS
82	109	108	124	146	147	144	100
80	105	104	119	140	143	141	95
77	100	101	115	134	139	137	90
75	96	97	111	128	136	134	85
72	91	94	106	122	132	131	80
70	87	91	102	116	128	128	75
67	82	88	98	111	124	124	70
65	78	84	93	104	120	121	65
62	73	81	89	98	117	118	60
60	69	77	84	92	113	114	55
57	64	74	80	86	109	111	50
55	60	71	76	80	105	108	45
52	55	67	71	74	101	104	40
50	51	64	67	68	98	101	35
47	46	60	62	62	94	98	30
45	42	57	58	56	90	95	25
42	37	54	54	50	86	91	20
40	33	50	49	44	82	88	15
37	28	47	45	38	79	85	10
35	24	43	40	32	75	81	5
32	19	40	36	26	71	78	0
57	64	74	80	86	109	111	*M*
62	85	75	55	42	30	21	*N*
8.2	15.0	11.3	14.7	20.1	12.5	11.0	σ

Table 57

Reciprocal of Ponderal Index
(cube root of weight in pounds over height in inches)

Age in years: 7	8	9	10	11	12	13		SS
14.15	14.88	14.93	14.81	15.48	15.38	15.22	...	100
14.04	14.70	14.75	14.68	15.26	15.19	15.01	...	95
13.92	14.52	14.56	14.55	15.03	15.00	14.80	...	90
13.81	14.34	14.37	14.42	14.81	14.82	14.58	...	85
13.69	14.16	14.18	14.29	14.58	14.63	14.37	...	80
13.58	13.98	14.00	14.17	14.36	14.44	14.16	...	75
13.46	13.80	13.81	14.04	14.13	14.25	13.95	...	70
13.35	13.62	13.62	13.91	13.91	14.06	13.74	...	65
13.23	13.44	13.44	13.78	13.68	13.88	13.52	...	60
13.12	13.26	13.25	13.65	13.46	13.69	13.31	...	55
13.00	13.08	13.06	13.54	13.23	13.50	13.10	...	50
12.89	12.90	12.86	13.41	13.01	13.31	12.89	...	45
12.77	12.72	12.69	13.28	12.78	13.12	12.68	...	40
12.66	12.54	12.50	13.15	12.56	12.94	12.46	...	35
12.54	12.36	12.31	13.02	12.33	12.75	12.25	...	30
12.43	12.18	12.13	12.90	12.11	12.56	12.04	...	25
12.31	12.00	11.94	12.77	11.88	12.37	11.83	...	20
12.20	11.82	11.75	12.64	11.66	12.18	11.62	...	15
12.08	11.64	11.57	12.51	11.43	12.00	11.40	...	10
11.97	11.46	11.38	12.38	11.21	11.81	11.19	...	5
11.85	11.28	11.19	12.26	10.98	11.62	10.98	...	0
13.00	13.08	13.06	13.54	13.23	13.50	13.10	...	*M*
63	83	63	55	46	30	20	...	*N*
0.383	0.600	0.623	0.426	0.749	0.626	0.706	...	σ

Table 58

Chest Expansion (inches)

Age in years: 6	7	8	9	10	11	12	13	14		SS
3.1	4.4	4.3	4.8	4.5	5.3	5.5	6.9	5.6	.....	100
3.0	4.2	4.1	4.6	4.3	5.1	5.3	6.6	5.3	.....	95
2.9	4.0	3.9	4.4	4.2	4.8	5.0	6.2	5.1	.....	90
2.8	3.8	3.8	4.2	4.0	4.6	4.8	5.9	4.8	.....	85
2.7	3.6	3.6	4.0	3.8	4.4	4.6	5.5	4.5	.....	80
2.7	3.5	3.4	3.8	3.7	4.2	4.4	5.2	4.3	.....	75
2.6	3.3	3.2	3.6	3.5	3.9	4.1	4.8	4.0	.....	70
2.5	3.1	3.0	3.4	3.3	3.7	3.9	4.5	3.7	.....	65
2.4	2.9	2.9	3.2	3.1	3.5	3.7	4.1	3.4	.....	60
2.3	2.7	2.7	3.0	3.0	3.2	3.4	3.8	3.2	.....	55
2.2	2.5	2.5	2.8	2.8	3.0	3.2	3.4	2.9	.....	50
2.1	2.3	2.3	2.6	2.6	2.8	3.0	3.1	2.6	.....	45
2.0	2.1	2.1	2.4	2.5	2.5	2.7	2.7	2.4	.....	40
1.9	1.9	2.0	2.2	2.3	2.3	2.5	2.4	2.1	.....	35
1.8	1.7	1.8	2.0	2.1	2.1	2.3	2.0	1.8	.....	30
1.8	1.6	1.6	1.8	2.0	1.9	2.1	1.7	1.6	.....	25
1.7	1.4	1.4	1.6	1.8	1.6	1.8	1.3	1.3	.....	20
1.6	1.2	1.2	1.4	1.6	1.4	1.6	1.0	1.0	.....	15
1.5	1.0	1.1	1.2	1.4	1.2	1.4	0.6	0.7	.....	10
1.4	0.8	0.9	1.0	1.3	0.9	1.1	0.2	0.5	.....	5
1.3	0.6	0.7	0.8	1.1	0.7	0.9	0	0.2	.....	0
2.2	2.5	2.5	2.8	2.8	3.0	3.2	3.4	2.9	.....	*M*
8	55	90	86	87	70	43	22	6	.....	*N*
0.29	0.62	0.59	0.65	0.55	0.76	0.75	1.16	0.90	.....	σ

Table 59

Expanded Chest Girth Minus Abdominal Girth (inches)

Age in years: 6	7	8	9	10	11	12	13	14	SS
5.5	7.6	7.2	8.8	9.0	9.8	9.0	10.8	8.4	100
5.3	7.3	6.9	8.4	8.5	9.3	8.6	10.2	7.9	95
5.1	6.9	6.6	7.9	8.1	8.7	8.1	9.6	7.5	90
5.0	6.6	6.3	7.5	7.6	8.2	7.7	8.9	7.0	85
4.8	6.2	6.0	7.0	7.1	7.6	7.2	8.3	6.6	80
4.6	5.9	5.7	6.6	6.7	7.1	6.8	7.7	6.1	75
4.4	5.5	5.4	6.1	6.2	6.5	6.4	7.1	5.6	70
4.2	5.2	5.1	5.7	5.7	6.0	5.9	6.5	5.2	65
4.1	4.9	4.8	5.2	5.2	5.4	5.5	5.8	4.7	60
3.9	4.6	4.5	4.8	4.8	4.9	5.0	5.2	4.3	55
3.7	4.2	4.2	4.3	4.3	4.3	4.6	4.6	3.8	50
3.5	3.9	3.9	3.9	3.8	3.8	4.1	4.0	3.3	45
3.3	3.5	3.6	3.4	3.4	3.2	3.7	3.4	2.9	40
3.2	3.2	3.3	3.0	2.9	2.7	3.2	2.7	2.4	35
3.0	2.8	3.0	2.5	2.4	2.1	2.8	2.1	2.0	30
2.8	2.5	2.7	2.1	2.0	1.6	2.3	1.5	1.5	25
2.6	2.1	2.4	1.6	1.5	1.0	1.9	0.9	1.0	20
2.4	1.8	2.1	1.2	1.0	0.5	1.4	0.3	0.6	15
2.3	1.4	1.8	0.7	0.5	−0.9	1.0	−0.7	0.1	10
2.1	1.1	1.5	0.3	0.1	−0.4	0.5	−1.0	−0.4	5
1.9	0.7	1.2	−0.2	−0.6	−1.8	0.1	−1.4	−0.9	0
3.7	4.2	4.2	4.3	4.3	4.3	4.6	4.6	3.8	*M*
8	55	90	86	87	70	43	22	6	*N*
0.61	1.17	1.01	1.51	1.56	1.83	1.48	2.08	1.54	σ

Table 60

Sum of Six Fat Folds (mm.)

Age in years: 7	8	9	10	11	12	SS
29	5	6	4	0	60	100
36	13	14	14	9	67	95
42	21	22	24	20	73	90
48	29	31	34	32	80	85
55	37	39	44	43	86	80
62	45	47	54	54	93	75
68	53	55	63	65	100	70
75	61	63	73	76	106	65
81	69	72	83	88	113	60
88	77	80	93	99	119	55
94	85	88	103	110	126	50
101	93	96	113	121	133	45
107	101	104	123	132	139	40
114	109	112	133	144	146	35
120	117	120	143	155	152	30
127	125	129	153	166	159	25
133	133	137	162	177	166	20
140	141	145	172	188	172	15
146	149	153	182	200	179	10
153	158	161	192	211	185	5
159	166	169	202	222	192	0
94	85	88	103	110	126	*M*
30	61	69	97	87	75	*N*
21.8	26.8	27.2	32.9	37.3	21.9	σ

Table 61

Strength (pounds)—Age 7 Years

Right Hand	Left Hand	Back	Legs	Total	Strength/Weight		SS
48	42	165	210	420	7.32	......	100
46	40	157	200	402	7.01	......	95
43	38	150	189	385	6.70	......	90
41	36	143	178	367	6.39	......	85
38	33	135	168	349	6.08	......	80
35	31	128	157	331	5.77	......	75
33	29	121	146	314	5.46	......	70
30	27	113	135	296	5.15	......	65
28	25	106	125	278	4.84	......	60
25	22	99	114	261	4.53	......	55
23	20	91	103	243	4.22	......	50
20	18	84	93	225	3.91	......	45
18	15	77	82	207	3.60	......	40
15	13	69	71	190	3.29	......	35
13	11	62	61	171	2.98	......	30
10	9	55	50	154	2.67	......	25
8	6	47	39	137	2.36	......	20
5	4	40	29	119	2.05	......	15
3	2	33	18	101	1.74	......	10
0	0	25	7	83	1.43	......	5
..	..	18	0	66	1.12	......	0
22.94	19.92	91.23	103.40	242.83	4.22	......	*M*
53	53	53	53	53	52	......	*N*
8.37	7.51	24.44	35.65	59.06	1.03	......	σ

Table 62

Strength (pounds)—Age 8 Years

Right Hand	Left Hand	Back	Legs	Total	Strength/Weight		SS
51	39	204	272	507	7.83	......	100
48	37	195	248	484	7.49	......	95
45	36	185	244	461	7.15	......	90
43	34	176	230	439	6.81	......	85
40	32	166	216	416	6.48	......	80
38	31	156	203	393	6.13	......	75
35	29	147	189	370	5.79	......	70
33	28	137	175	347	5.45	......	65
30	26	128	161	324	5.11	......	60
28	24	118	147	301	4.77	......	55
25	23	108	134	278	4.43	......	50
23	21	99	120	256	4.09	......	45
20	19	89	106	233	3.75	......	40
18	18	80	92	210	3.41	......	35
15	16	70	78	187	3.07	......	30
12	15	60	65	164	2.73	......	25
10	13	51	51	141	2.39	......	20
7	11	41	37	118	2.05	......	15
5	10	32	23	96	1.71	......	10
2	8	22	9	73	1.37	......	5
0	6	12	0	50	1.03	......	0
25.16	22.65	108.33	133.59	278.46	4.43	......	*M*
79	78	78	78	78	78	......	*N*
8.47	5.41	32.01	46.05	76.23	1.12	......	σ

Table 63

Strength (pounds)—Age 9 Years

Right Hand	Left Hand	Back	Legs	Total	Strength/ Weight	SS
58	57	225	299	580	8.01	 100
55	54	216	284	555	7.67	 95
52	51	206	270	530	7.33	 90
50	49	196	255	506	6.99	 85
48	46	186	240	481	6.65	 80
45	43	176	226	457	6.31	 75
42	40	166	211	432	5.97	 70
40	37	156	197	407	5.63	 65
38	34	146	182	383	5.29	 60
35	31	136	168	358	4.95	 55
32	29	126	153	334	4.61	 50
30	26	116	139	309	4.27	 45
28	23	106	124	284	3.93	 40
25	20	96	109	260	3.59	 35
22	17	86	95	235	3.25	 30
20	14	76	80	211	2.91	 25
18	12	66	66	186	2.57	 20
15	9	56	51	161	2.23	 15
12	6	46	37	139	1.89	 10
10	3	36	22	112	1.55	 5
8	0	26	7	88	1.21	 0
32.51	28.62	125.78	153.12	333.60	4.61	...... M
77	77	77	77	77	76	...... N
8.35	9.49	33.22	48.57	81.89	1.13	...... σ

Table 64

Strength (pounds)—Age 10 Years

Right Hand	Left Hand	Back	Legs	Total	Strength/ Weight	SS
64	62	235	316	628	8.95	 100
62	58	225	302	603	8.57	 95
59	55	216	288	578	8.19	 90
56	52	207	274	554	7.81	 85
54	49	197	261	529	7.43	 80
51	46	188	247	504	7.05	 75
48	43	179	233	479	6.67	 70
46	40	169	219	455	6.29	 65
43	37	160	205	430	5.91	 60
40	34	151	191	405	5.53	 55
38	31	141	177	381	5.15	 50
35	28	132	164	356	4.77	 45
32	25	123	150	331	4.39	 40
30	22	113	136	306	4.01	 35
27	19	104	122	282	3.63	 30
24	16	95	108	257	3.25	 25
22	13	85	94	232	2.87	 20
19	10	76	80	208	2.49	 15
16	7	67	67	183	2.11	 10
13	4	58	53	158	1.73	 5
11	0	48	39	133	1.35	 0
37.60	31.02	141.38	177.43	380.60	5.15	...... M
105	105	105	105	105	90	...... N
8.94	10.16	31.05	46.21	82.41	1.28	...... σ

Table 65

Strength (pounds)—Age 11 Years

Right Hand	*Left Hand*	*Back*	*Legs*	*Total*	*Strength/ Weight*	*SS*
73	65	248	325	686	8.44	 100
70	62	238	311	658	8.07	 95
67	59	229	298	630	7.70	 90
63	56	219	284	602	7.33	 85
60	52	209	270	574	6.96	 80
57	49	200	256	546	6.59	 75
54	46	190	242	518	6.22	 70
51	43	180	229	490	5.85	 65
48	40	171	215	462	5.48	 60
44	37	161	201	434	5.11	 55
41	34	151	188	406	4.74	 50
38	30	142	174	378	4.37	 45
35	27	132	160	350	4.00	 40
32	24	122	146	322	3.63	 35
28	21	113	132	294	3.26	 30
25	18	103	119	266	2.89	 25
22	15	93	105	238	2.52	 20
19	12	84	91	210	2.15	 15
16	8	74	78	182	1.78	 10
13	5	64	64	154	1.41	 5
9	2	55	50	126	1.04	 0
41.17	33.59	151.29	187.50	405.95	4.74	...... *M*
105	105	105	105	105	92	...... *N*
10.56	10.51	32.17	45.82	93.19	1.24	...... σ

Table 66

Strength (pounds)—Age 12 Years

Right Hand	*Left Hand*	*Back*	*Legs*	*Total*	*Strength/ Weight*	*SS*
137	114	382	490	1060	9.65	 100
129	108	363	465	1009	9.19	 95
122	102	344	441	956	8.73	 90
114	95	325	416	903	8.27	 85
106	89	306	392	851	7.81	 80
99	83	287	367	798	7.35	 75
91	77	268	342	745	6.89	 70
84	70	249	318	692	6.43	 65
76	64	230	293	639	5.97	 60
69	58	211	269	586	5.51	 55
61	51	192	244	533	5.05	 50
54	45	173	220	480	4.59	 45
46	39	154	195	427	4.13	 40
39	33	135	171	375	3.67	 35
31	26	116	146	322	3.21	 30
24	20	97	121	269	2.75	 25
16	14	78	97	216	2.29	 20
9	8	59	72	163	1.83	 15
1	1	40	48	110	1.37	 10
0	0	21	23	57	0.91	 5
...	...	2	0	4	0.45	 0
61.34	51.47	192.39	244.22	533.26	5.05	...... *M*
109	109	109	109	109	103	...... *N*
25.05	20.88	63.35	81.82	176.29	1.53	...... σ

Table 67

Strength (pounds)—Age 13 Years

Right Hand	*Left Hand*	*Back*	*Legs*	*Total*	*Strength/Weight*	*SS*
127	106	403	536	1088	8.52	100
121	102	385	510	1042	8.20	95
116	98	367	485	995	7.88	90
110	93	348	459	948	7.56	85
104	89	330	433	901	7.24	80
99	84	312	407	855	6.92	75
93	80	294	381	808	6.60	70
87	75	276	355	761	6.28	65
82	71	258	329	714	5.96	60
76	66	240	303	668	5.64	55
70	62	221	278	621	5.32	50
65	57	203	252	574	5.00	45
59	53	185	226	527	4.68	40
54	48	167	200	481	4.36	35
48	44	149	174	434	4.04	30
42	39	131	148	387	3.72	25
37	35	113	122	340	3.40	20
31	30	94	97	294	3.08	15
25	26	76	71	247	2.76	10
20	21	58	45	200	2.44	5
14	17	40	19	153	2.12	0
70.45	61.66	221.41	277.61	620.77	5.32	*M*
71	70	71	71	71	71	*N*
18.84	14.94	60.45	86.19	155.82	1.05	σ

Table 68

Visual Reaction Time—Vertical Jump (seconds)

AGE IN YEARS 6	7	8	9	10	11	12	13	*SS*
.219	.202	.192	.217	.170	.131	.231	.139	100
.249	.228	.218	.237	.194	.157	.247	.163	95
.278	.254	.243	.257	.218	.183	.263	.187	90
.307	.280	.269	.277	.242	.209	.278	.211	85
.336	.306	.294	.297	.266	.235	.295	.235	80
.366	.332	.320	.317	.290	.261	.311	.259	75
.395	.358	.345	.337	.313	.287	.327	.283	70
.424	.384	.371	.357	.338	.313	.343	.307	65
.454	.410	.396	.377	.362	.339	.359	.331	60
.483	.436	.422	.397	.386	.365	.375	.355	55
.512	.462	.447	.417	.410	.391	.391	.379	50
.542	.488	.473	.437	.434	.417	.407	.403	45
.571	.514	.498	.457	.458	.443	.423	.427	40
.600	.540	.524	.477	.482	.469	.439	.451	35
.630	.566	.549	.497	.506	.495	.455	.475	30
.659	.592	.575	.517	.530	.521	.471	.499	25
.688	.618	.600	.537	.554	.547	.487	.523	20
.717	.644	.626	.557	.578	.573	.503	.547	15
.747	.670	.651	.577	.602	.599	.519	.571	10
.776	.696	.677	.597	.626	.625	.535	.595	5
.805	.722	.702	.617	.650	.651	.551	.619	0
.512	.462	.447	.417	.410	.391	.391	.379	*M*
10	51	76	71	47	33	19	11	*N*
.0978	.0870	.0852	.0660	.0782	.0885	.0539	.0805	σ

Table 69

Auditory Reaction Time—Vertical Jump (seconds)

Age in Years 6	7	8	9	10	11	12	13		SS
.244	.190	.193	.213	.199	.129	.188	.090	...	100
.268	.216	.217	.231	.218	.154	.204	.116	...	95
.291	.242	.241	.249	.237	.179	.222	.142	...	90
.315	.268	.265	.267	.256	.204	.239	.168	...	85
.338	.294	.289	.285	.275	.229	.256	.194	...	80
.362	.320	.313	.303	.294	.254	.273	.220	...	75
.385	.346	.337	.321	.313	.279	.290	.246	...	70
.409	.372	.361	.339	.332	.304	.307	.272	...	65
.432	.398	.385	.357	.351	.329	.324	.298	...	60
.456	.424	.409	.375	.370	.354	.341	.324	...	55
.479	.450	.433	.393	.389	.379	.358	.350	...	50
.503	.476	.457	.411	.408	.404	.375	.376	...	45
.526	.502	.481	.429	.427	.429	.392	.402	...	40
.550	.528	.505	.447	.446	.454	.409	.428	...	35
.573	.554	.529	.465	.465	.479	.426	.454	...	30
.597	.580	.553	.483	.484	.504	.443	.480	...	25
.620	.606	.577	.501	.503	.529	.460	.506	...	20
.644	.632	.601	.519	.522	.554	.477	.532	...	15
.667	.658	.625	.537	.541	.579	.494	.558	...	10
.691	.684	.649	.555	.560	.604	.511	.584	...	5
.714	.710	.673	.573	.579	.629	.528	.610	...	0
.479	.450	.433	.393	.389	.379	.358	.350	...	*M*
10	51	76	71	47	33	19	11	...	*N*
.0782	.0882	.0810	.0611	.0642	.0823	.0575	.0884	...	σ

Table 70

Combination Visual and Auditory Reaction Time—Vertical Jump (seconds)

Age in Years 6	7	8	9	10	11	12	13		SS
.194	.200	.147	.193	.199	.087	.202	.077	...	100
.222	.225	.173	.213	.218	.115	.218	.105	...	95
.250	.250	.199	.233	.237	.143	.234	.133	...	90
.277	.275	.225	.253	.256	.171	.250	.161	...	85
.305	.300	.251	.273	.275	.199	.266	.189	...	80
.332	.325	.277	.293	.294	.227	.282	.217	...	75
.360	.350	.303	.313	.313	.255	.298	.245	...	70
.388	.375	.329	.333	.332	.283	.314	.273	...	65
.415	.400	.355	.353	.351	.311	.330	.301	...	60
.443	.425	.381	.373	.370	.339	.346	.329	...	55
.470	.450	.433	.393	.389	.367	.362	.357	...	50
.498	.475	.459	.413	.408	.395	.378	.385	...	45
.526	.500	.485	.433	.427	.423	.394	.413	...	40
.553	.525	.511	.453	.446	.451	.410	.441	...	35
.581	.550	.537	.473	.465	.479	.426	.469	...	30
.608	.575	.563	.493	.484	.507	.442	.497	...	25
.636	.600	.589	.513	.503	.535	.458	.525	...	20
.664	.625	.615	.533	.522	.563	.474	.553	...	15
.691	.650	.641	.553	.541	.591	.490	.581	...	10
.719	.675	.667	.573	.560	.619	.506	.609	...	5
.746	.700	.693	.593	.579	.647	.522	.637	...	0
.470	.450	.433	.393	.389	.367	.362	.357	...	*M*
10	51	76	71	47	33	19	11	...	*N*
.0921	.0828	.0860	.0660	.0617	.0930	.0525	.0931	...	σ

Table 71

18-Item Test (points)

AGE IN YEARS										
6	7	8	9	10	11	12	13	14	15	SS
13	12	12	15	15	16	..	..	..	..	100
12	11	12	14	14	16	18	18	..	..	95
11	11	11	13	14	15	17	17	18	18	90
10	10	10	12	13	14	16	16	17	18	85
9	9	9	11	12	13	15	15	17	17	80
9	8	9	10	11	12	14	14	16	16	75
8	8	8	9	10	11	13	13	15	15	70
7	7	7	8	9	11	12	12	14	14	65
6	6	6	7	9	10	11	12	13	14	60
5	5	6	7	8	9	10	11	12	13	55
4	5	5	6	7	8	9	10	11	12	50
3	4	4	5	6	7	8	9	10	11	45
2	3	3	4	5	6	7	8	9	10	40
2	2	3	3	4	6	6	7	8	9	35
1	2	2	2	4	5	5	6	7	8	30
0	1	1	1	3	4	4	5	7	8	25
	0	0	0	2	3	3	4	6	7	20
..	..	..	..	1	2	2	3	5	6	15
..	..	..	..	0	1	1	3	4	5	10
..	..	..	..	..	0	0	2	3	4	5
..	..	..	..	..	..	..	1	2	3	0
4.20	4.73	4.99	5.62	6.86	8.02	9.03	9.79	11.13	11.79	*M*
10	52	79	77	108	146	115	137	108	29	*N*
2.89	2.50	2.51	2.97	2.80	2.81	3.54	3.01	3.02	2.76	*σ*

Table 72

Backward Extension (inches)

AGE IN YEARS							
7	8	9	10	11	12	13	SS
21.2	23.6	21.6	24.1	25.1	24.1	23.6	100
20.3	22.5	20.6	23.1	24.0	23.1	22.6	95
19.3	21.4	19.6	22.1	22.9	22.2	21.6	90
18.4	20.3	18.6	21.1	21.8	21.2	20.6	85
17.4	19.2	17.6	20.1	20.7	20.2	19.6	80
16.5	18.1	16.6	19.1	19.6	19.2	18.6	75
15.5	17.1	15.6	18.1	18.5	18.2	17.6	70
14.6	16.0	14.6	17.1	17.4	17.3	16.6	65
13.6	14.8	13.6	16.1	16.3	16.3	15.6	60
12.7	13.8	12.6	15.1	15.2	15.3	14.6	55
11.7	12.7	11.6	14.1	14.1	14.3	13.6	50
10.8	11.6	10.6	13.1	13.0	13.3	12.6	45
9.8	10.5	9.6	12.1	11.9	12.4	11.6	40
8.9	9.4	8.6	11.1	10.8	11.4	10.6	35
7.9	8.3	7.6	10.1	9.7	10.4	9.6	30
7.0	7.2	6.6	9.1	8.6	9.4	8.6	25
6.0	6.2	5.6	8.1	7.5	8.4	7.6	20
5.1	5.1	4.6	7.1	6.4	7.5	6.6	15
4.1	4.0	3.6	6.1	5.3	6.5	5.6	10
3.2	2.9	2.6	5.1	4.2	5.5	4.6	5
2.2	1.8	1.6	4.1	3.1	4.5	3.6	0
11.7	12.7	11.6	14.1	14.1	14.3	13.6	*M*
65	71	65	53	39	23	13	*N*
3.18	3.65	3.35	3.31	3.66	3.28	3.39	*σ*

Table 73

Forward Flexion (inches)

Age in Years: 7	8	9	10	11	12	13	SS
1.8	0.3	3.0	1.2	2.5	4.0	5.3	. . . 100
2.5	1.2	3.8	2.0	3.4	4.6	6.1	. . . 95
3.2	2.1	4.6	2.8	4.3	5.2	6.9	. . . 90
3.9	3.0	5.4	3.7	5.1	5.9	7.7	. . . 85
4.5	4.0	6.1	4.5	6.0	6.6	8.5	. . . 80
5.2	4.9	7.0	5.4	6.9	7.2	9.1	. . . 75
5.9	5.8	7.7	6.3	7.7	7.9	9.8	. . . 70
6.5	6.7	8.4	7.2	8.6	8.5	10.5	. . . 65
7.2	7.6	9.2	8.1	9.4	9.2	11.2	. . . 60
7.9	8.5	10.0	8.9	10.3	9.9	11.9	. . . 55
8.5	9.4	10.8	9.8	11.1	10.5	12.5	. . . 50
9.2	10.3	11.5	10.7	12.0	11.2	13.2	. . . 45
9.9	11.2	12.3	11.6	12.9	11.8	13.9	. . . 40
10.6	12.1	13.0	12.5	13.7	12.5	14.6	. . . 35
11.2	13.1	13.8	13.3	14.6	13.2	15.3	. . . 30
11.9	14.0	14.6	14.2	15.5	13.8	15.9	. . . 25
12.6	14.9	15.4	15.0	16.3	14.5	16.6	. . . 20
13.2	15.8	16.1	15.8	17.2	15.1	17.3	. . . 15
13.9	16.7	17.0	16.5	18.0	15.8	18.0	. . . 10
14.6	17.6	17.7	17.4	18.9	16.5	18.6	. . . 5
15.2	18.5	18.5	18.3	19.8	17.1	19.3	. . . 0
8.5	9.4	10.8	9.8	11.1	10.5	12.5	. . . *M*
60	69	56	49	37	19	11	. . . *N*
2.22	3.03	2.58	2.92	2.85	2.21	2.27	. . . σ

Table 74

Floor Push-Ups (number)

Age in Years: 8	9	10	11	12	13	SS
20	25	25	26	26	30	 100
19	23	23	24	24	28	 95
17	22	22	23	23	26	 90
16	20	20	21	21	24	 85
15	18	18	20	19	22	 80
14	17	17	18	17	20	 75
12	15	15	15	15	18	 70
11	13	13	14	14	16	 65
10	11	11	12	12	14	 60
8	10	10	11	11	12	 55
7	8	8	9	9	10	 50
6	6	6	8	7	8	 45
4	5	5	6	5	6	 40
3	3	3	5	4	4	 35
2	1	1	3	2	2	 30
1	0	0	2	0	0	 25
0	..	..	0	..	..	 20
..	..	..	..	..	..	 15
..	..	..	..	..	..	 10
..	..	..	..	..	..	 5
..	..	..	..	..	..	 0
7	8	8	9	9	10	. . . . *M*
71	69	80	48	33	16	. . . . *N*
4.3	5.7	5.6	5.1	6.1	6.6	. . . . σ

Table 75

Agility Run (seconds)

Age in Years 7	8	9	10	11	12	13	SS
18.2	17.4	17.8	16.8	16.5	14.6	15.6	100
18.7	18.0	18.3	17.3	17.0	15.2	16.1	95
19.2	18.6	18.8	17.8	17.5	15.8	16.6	90
19.7	19.2	19.3	18.3	18.0	16.4	17.1	85
20.2	19.8	19.8	18.8	18.5	17.0	17.6	80
20.8	20.4	20.3	19.3	19.0	17.6	18.1	75
21.3	21.0	20.8	19.8	19.5	18.1	18.6	70
21.8	21.6	21.3	20.3	20.0	18.7	19.1	65
22.3	22.2	21.8	20.8	20.5	19.3	19.6	60
22.8	22.8	22.3	21.3	21.0	19.9	20.1	55
23.3	23.4	22.8	21.8	21.5	20.4	20.6	50
23.8	24.0	23.3	22.3	22.0	21.0	21.1	45
24.3	24.6	23.8	22.8	22.5	21.6	21.6	40
24.8	25.2	24.3	23.3	23.0	22.2	22.1	35
25.3	25.8	24.8	23.8	23.5	22.8	22.6	30
25.8	26.4	25.3	24.3	24.0	23.4	23.1	25
26.4	27.0	25.8	24.8	24.5	23.9	23.6	20
26.9	27.6	26.3	25.3	25.0	24.5	24.1	15
27.4	28.2	26.8	25.8	25.5	25.1	24.6	10
27.9	28.8	27.3	26.3	26.0	25.7	25.1	5
28.4	29.4	27.8	26.8	26.5	26.2	25.6	0
23.3	23.4	22.8	21.8	21.5	20.4	20.6	*M*
35	59	59	54	27	12	8	*N*
1.71	2.10	1.60	1.58	1.67	1.94	1.68	σ

Table 76

Endurance Hops (number)

Age in Years 7	8	9	10	11	12	13	SS
917	940	963	1110	1002	1099	1197	100
855	876	901	1043	948	1034	1134	95
793	813	839	976	894	969	1071	90
731	749	777	909	840	904	1008	85
669	686	715	842	786	839	945	80
607	622	653	775	732	774	882	75
545	558	591	708	678	709	819	70
483	495	529	641	624	644	756	65
421	431	467	574	570	579	693	60
359	368	405	507	516	514	630	55
297	304	343	440	462	449	567	50
235	240	281	373	408	384	504	45
173	177	219	306	354	319	441	40
111	113	157	239	300	254	378	35
49	50	95	172	246	189	315	30
0	0	33	105	192	124	252	25
...	...	0	38	138	59	189	20
...	...	...	0	84	0	126	15
..	...	...	...	30	...	63	10
...	...	...	...	0	...	0	5
...	...	...	...	...	...	...	0
297	304	343	440	462	449	567	*M*
59	71	51	59	33	25	8	*N*
207.4	212.1	206.5	223.9	180.9	216.6	210.9	σ

Table 77

Standing Broad Jump (inches)

Age in years 7	8	9	10	11	12	13	SS
69	73	64	80	80	90	81	100
67	70	63	78	78	87	79	95
65	68	62	75	76	84	78	90
63	65	61	73	74	81	76	85
61	64	60	71	72	78	74	80
59	62	59	68	70	75	72	75
57	59	58	66	68	72	71	70
55	57	56	64	66	69	69	65
53	55	55	62	64	66	68	60
51	53	54	59	62	64	66	55
49	50	53	57	60	61	64	50
47	49	52	55	58	59	62	45
45	47	51	52	56	57	61	40
43	45	50	50	54	53	59	35
41	43	49	48	52	50	57	30
39	41	48	45	50	47	55	25
37	39	47	43	48	44	54	20
35	36	45	41	46	41	52	15
33	34	44	39	44	38	50	10
31	32	43	36	42	35	49	5
29	30	42	34	40	32	47	0
49	50	53	57	60	61	64	*M*
61	75	59	54	39	12	14	*N*
6.7	7.2	3.7	7.8	6.8	10.9	5.5	σ

Table 78

Running Broad Jump (inches)

Age in years 7	8	9	10	11	SS
115	145	127	141	163	100
111	138	123	137	157	95
106	131	118	132	151	90
101	124	114	128	144	85
96	118	110	123	138	80
92	111	106	119	132	75
87	104	102	114	126	70
82	97	98	109	120	65
78	90	94	105	114	60
73	83	89	100	108	55
68	77	85	96	102	50
63	70	81	91	96	45
59	63	77	87	90	40
54	56	73	82	84	35
49	49	69	78	78	30
44	42	65	73	71	25
40	36	61	69	65	20
35	29	56	64	59	15
30	22	52	59	53	10
26	15	48	55	47	5
21	8	44	50	41	0
68	77	85	96	102	*M*
34	45	58	42	39	*N*
15.7	19.4	14.7	15.2	20.3	σ

Table 79

Running High Jump (inches)

Age in years 7	8	9	10	11	SS
39	40	49	43	52	100
38	39	47	42	51	95
36	38	45	41	49	90
35	37	43	40	48	85
34	35	42	39	46	80
33	34	40	38	44	75
32	33	38	37	43	70
30	32	36	36	41	65
29	31	34	35	39	60
28	30	33	34	38	55
27	28	31	33.5	36	50
26	27	29	33	35	45
24	26	27	32	33	40
23	25	25	31	31	35
22	24	23	30	30	30
21	22	22	29	28	25
19	21	20	28	26	20
18	20	18	27	25	15
17	19	16	26	23	10
16	18	14	25	22	5
15	17	13	24	20	0
27	28	31	33.5	36	*M*
30	62	57	44	44	*N*
4.0	3.9	3.6	3.3	5.4	σ

Table 80

8-Pound Shot-Put (inches)

Age in Years 8	9	10	SS
182	198	236	100
175	191	228	95
168	185	220	90
161	178	213	85
154	171	205	80
147	164	198	75
140	157	190	70
132	150	182	65
125	143	175	60
118	137	167	55
111	130	160	50
104	123	152	45
97	116	144	40
90	109	137	35
83	102	129	30
76	95	121	25
69	89	114	20
62	82	106	15
55	75	99	10
47	68	91	5
40	61	83	0
111	130	160	*M*
32	29	20	*N*
23.6	22.9	25.4	σ

Table 81

Balance Beam (score)

Age in Years 7	8	9	10	11	12	13	SS
27	30	30	30	30	30	30	100
25	29	29*	29	29	29	29	95
24	28*	26	29	29	29	29	90
22	28	26	29*	29*	29*	29	85
20	26	24	29	28	29	28	80
19	24	23	27	27	28	27	75
17	21	21	25	25	26	27*	70
15	19	19	23	23	24	26	65
13	17	17	21	21	22	24	60
12	15	16	19	20	20	21	55
10	13	14	17	18	18	19	50
8	11	12	15	16	16	17	45
7	9	10	13	14	14	14	40
5	7	9	11	13	12	12	35
3	5	7	9	11	10	9	30
2	3	5	7	9	9	7	25
0	1	3	5	7	7	5	20
..	0	2	3	6	5	2	15
..	..	0	1	4	3	0	10
..	..	..	0	2	1	..	5
..	..	..	..	0	0	..	0
10	13	14	17	18	18	19	*M*
53	70	58	59	41	12	8	*N*
5.7	7.0	5.5	6.8	5.7	6.2	7.9	σ

* Highest possible score is 30. Arbitrary scaling above asterisks.

Table 82

Chins (standard score percentage for each number of chins)

No. of Chins	Age in Years 7	8	9	10	11	12
5.5	..	..	..	97	..	..
5.0	..	97	100	91	100	98
4.5	99	90	93	85	93	92
4.0	92	83	87	79	87	86
3.5	85	76	80	73	81	80
3.0	78	70	74	67	74	73
2.5	71	63	67	61	68	67
2.0	64	56	61	55	61	61
1.5	57	49	54	49	55	55
1.0	50	45	45	45	45	45
0.5	35	35	30	30	30	30
0	0	0	0	0	0	0
M	1.00	1.54	1.18	1.54	1.14	1.12
N	24	56	53	53	11	12
σ	1.18	1.23	1.27	1.40	1.29	1.34

Note.—Standard scores for 1.0, 0.5, and 0 chins were derived from arbitrary smoothing of the curve.

Table 83

Dips (standard score percentage for each number of dips)

No. of Dips	Age in Years 7	8	9	10	11	12
9.5	..	..	..	..	99	100
9.0	..	..	..	..	95	96
8.5	..	..	..	97	92	93
8.0	..	..	98	94	89	89
7.5	99	99	95	90	86	85
7.0	95	95	91	87	82	81
6.5	91	91	87	83	79	78
6.0	86	86	83	80	76	74
5.5	82	82	79	76	72	70
5.0	78	78	75	72	69	67
4.5	73	73	71	69	66	63
4.0	69	69	67	65	63	59
3.5	64	65	63	62	59	56
3.0	60	60	59	58	56	52
2.5	56	56	55	55	53	48
2.0	51	51	52	51	49	47
1.5	45	45	45	45	45	45
1.0	30	30	30	30	30	30
0.5	15	15	15	15	15	15
0	0	0	0	0	0	0
M	1.87	1.81	1.80	2.08	2.75	1.56
N	26	57	54	53	12	12
σ	1.90	1.91	2.13	2.37	2.54	2.25

Note.—Standard scores for 1.5, 1.0, 0.5, and 0 dips were derived from arbitrary smoothing of the curve.

Table 84

Vertical Jump (inches)

Age in Years 7	8	9	10	11	12	13	SS
12.4	15.4	14.7	16.3	16.7	19.0	17.0	100
12.0	14.8	14.2	15.7	16.2	18.4	16.6	95
11.5	14.2	13.8	15.2	15.6	17.7	16.1	90
11.1	13.6	13.4	14.7	15.1	17.1	15.6	85
10.6	13.0	13.0	14.2	14.5	16.5	15.1	80
10.2	12.4	12.5	13.6	14.0	15.9	14.7	75
9.8	11.8	12.1	13.1	13.5	15.2	14.2	70
9.3	11.3	11.7	12.6	12.9	14.6	13.7	65
8.9	10.7	11.2	12.0	12.4	14.0	13.2	60
8.4	10.1	10.8	11.5	11.8	13.3	12.8	55
8.0	9.5	10.4	11.0	11.3	12.7	12.3	50
7.6	8.9	9.9	10.4	10.8	12.1	11.8	45
7.1	8.3	9.5	9.9	10.2	11.4	11.4	40
6.7	7.7	9.1	9.4	9.7	10.8	10.9	35
6.2	7.1	8.6	8.8	9.1	10.2	10.4	30
5.8	6.5	8.2	8.3	8.6	9.6	10.0	25
5.4	6.0	7.8	7.8	8.1	8.9	9.5	20
5.0	5.4	7.4	7.3	7.5	8.3	9.0	15
4.5	4.8	7.0	6.7	7.0	7.7	8.5	10
4.0	4.2	6.5	6.2	6.4	7.0	8.1	5
3.6	3.6	6.1	5.7	5.9	6.4	7.6	0
8.0	9.5	10.4	11.0	11.3	12.7	12.3	*M*
27	57	55	50	12	12	8	*N*
1.48	1.98	1.43	1.77	1.80	2.11	1.58	σ

Table 85

60-Yard Dash (seconds)

Age in Years 7	8	9	10	11	12	13	SS
8.6	6.3	7.7	8.8	7.5	5.9	8.4	100
8.9	6.8	8.0	9.0	7.8	6.3	8.5	95
9.3	7.4	8.3	9.2	8.1	6.7	8.7	90
9.7	8.0	8.7	9.4	8.4	7.1	8.8	85
10.0	8.5	9.0	9.6	8.7	7.5	9.0	80
10.4	9.0	9.3	9.7	8.9	7.9	9.1	75
10.7	9.6	9.7	9.9	9.2	8.3	9.3	70
11.1	10.2	10.0	10.1	9.5	8.7	9.4	65
11.4	10.8	10.3	10.3	9.8	9.1	9.6	60
11.8	11.3	10.7	10.5	10.1	9.5	9.7	55
12.2	11.9	11.0	10.7	10.4	9.9	9.9	50
12.5	12.4	11.3	10.9	10.6	10.2	10.0	45
12.9	13.0	11.7	11.0	10.9	10.6	10.1	40
13.2	13.6	12.0	11.2	11.2	11.0	10.3	35
13.6	14.1	12.3	11.4	11.5	11.4	10.4	30
13.9	14.7	12.7	11.6	11.8	11.8	10.6	25
14.3	15.2	13.0	11.8	12.1	12.2	10.7	20
14.6	15.8	13.3	12.0	12.4	12.6	10.9	15
15.0	16.4	13.7	12.2	12.6	13.0	11.0	10
15.4	16.9	14.0	12.3	12.9	13.4	11.2	5
15.7	17.5	14.3	12.5	13.2	13.8	11.3	0
12.2	11.9	10.8	10.7	10.4	9.9	9.9	*M*
31	55	50	42	46	15	10	*N*
1.19	1.87	1.08	0.62	0.95	1.32	0.49	σ

Table 86

440-Yard Run (seconds)

Age 7	8	9	10	11	SS
58	68	69	46	63	100
60	73	73	53	67	95
62	79	76	59	71	90
64	85	80	66	76	85
74	91	84	73	80	80
84	97	87	79	84	75
94	102	91	86	89	70
104	108	94	92	93	65
114	114	98	99	97	60
124	119	102	106	101	55
134	125	105	112	106	50
144	131	109	119	110	45
154	136	113	125	114	40
164	142	116	132	118	35
174	148	120	138	123	30
184	154	123	145	127	25
194	159	127	152	131	20
204	165	131	158	135	15
214	171	134	165	140	10
224	176	138	171	144	5
234	182	142	178	148	0
134	125	105	112	106	*M*
10	21	23	25	26	*N*
33.3	19.0	12.1	22.0	14.2	σ

Table 87

600-Yard Run (seconds)

Age 7	8	9	10	11	12	SS
110	94	95	95	80	81	100
115	102	102	101	87	88	95
120	109	109	107	94	95	90
126	117	116	113	100	101	85
131	124	124	120	107	108	80
136	132	131	126	114	115	75
142	139	138	133	121	122	70
147	147	145	139	128	129	65
152	154	152	145	135	135	60
158	161	159	152	142	142	55
163	169	166	158	149	149	50
168	176	174	165	156	156	45
174	184	181	171	162	163	40
179	191	188	177	169	169	35
184	199	195	184	176	176	30
190	206	202	190	183	183	25
195	214	209	197	190	190	20
200	221	217	203	197	197	15
206	229	224	209	204	204	10
211	236	231	216	211	210	5
216	244	240	222	218	217	0
163	169	166	158	149	149	*M*
17	43	41	29	31	16	*N*
17.8	24.9	23.8	21.4	23.0	22.7	σ

Table 88

Drop-Off Index (seconds)

Age 7	8	9	10	11	SS
2	0	2	9	0	100
7	0	7	13	0	95
12	5	12	18	4	90
17	10	18	22	9	85
22	16	23	26	15	80
26	22	29	31	20	75
31	28	34	35	25	70
36	33	40	39	31	65
41	39	45	44	36	60
46	45	50	48	41	55
50	51	56	52	47	50
55	57	61	56	52	45
60	63	67	61	57	40
65	69	72	65	63	35
70	74	78	69	68	30
74	80	83	74	73	25
79	86	88	78	79	20
84	92	94	82	84	15
89	98	100	87	89	10
94	103	105	91	95	5
98	109	110	95	100	0
50	51	56	52	47	*M*
21	43	40	28	25	*N*
16.0	19.4	18.1	14.4	18.0	σ

Table 89

Treadmill Run, All-Out—5 mph, 8.6% Grade (seconds)

Age in Years 6	7	8	9	10	SS
315	135	185	277	278	100
300	130	178	268	270	95
286	126	173	258	262	90
271	122	167	249	254	85
256	117	160	239	246	80
241	113	154	230	238	75
226	109	148	220	230	70
212	104	142	211	222	65
197	100	136	201	214	60
182	96	130	192	206	55
167	92	124	182	198	50
153	87	118	173	190	45
138	83	112	163	183	40
123	79	106	154	175	35
108	74	100	144	167	30
93	70	94	135	159	25
79	66	88	125	151	20
64	62	81	116	143	15
49	57	75	106	135	10
34	53	69	97	127	5
20	49	63	87	119	0
167	92	124	182	198	*M*
6	27	35	27	15	*N*
49.27	14.33	20.29	31.68	26.48	σ

Table 90

Treadmill Run, All-Out—7 mph, 8.6% Grade (seconds)

Age in Years 8	9	10	11	12	13	SS
180	122	163	173	258	279	100
169	117	154	164	243	262	95
157	112	145	154	228	244	90
146	107	136	145	212	227	85
134	102	127	135	197	210	80
123	96	119	126	182	193	75
111	91	110	116	166	176	70
100	86	101	107	151	158	65
88	81	92	97	136	141	60
77	75	83	88	121	124	55
65	70	75	78	105	107	50
53	65	66	69	90	90	45
42	60	57	59	75	72	40
31	55	47	50	59	55	35
19	50	39	40	44	38	30
8	44	31	31	29	21	25
0	39	22	21	13	4	20
...	34	13	12	0	0	15
...	28	4	2	...	...	10
...	24	0	0	...	...	5
...	18	...	...	...	...	0
65	70	75	78	105	107	*M*
8	12	22	31	25	7	*N*
38.5	17.5	29.5	31.6	51.1	57.2	σ

Table 91

Schneider Index (points)

AGE IN YEARS 7	8	9	10	11	12	13	14	15	16	17		SS
18	16	17	14	17	19	22	22	..	..	22	.....	100
17	15	16	14	16	17	21	21	..	..	21	.....	95
16	14	15	13	15	16	20	19	22	22	20	.....	90
15	13	14	12	14	15	18	18	21	20	19	.....	85
13	12	13	11	13	14	17	17	19	19	18	.....	80
12	11	12	10	13	13	15	16	18	18	17	.....	75
11	10	11	9	12	12	14	14	17	16	16	.....	70
10	9	10	9	11	10	12	13	16	15	15	.....	65
9	8	9	8	10	9	11	12	14	14	14	.....	60
7	8	8	7	9	8	10	10	13	13	13	.....	55
6	7	7	6	8	7	8	9	12	11	12	....	50
5	6	6	5	7	6	7	8	11	10	11	.....	45
4	5	5	4	6	4	5	7	8	8	10	.....	40
3	4	4	3	5	3	4	5	8	8	9	.....	35
1	3	3	3	4	2	2	4	7	6	8	.....	30
0	2	2	2	3	1	1	3	6	5	7	.....	25
−1	1	1	1	2	0	0	1	4	4	6	.....	20
−2	0	0	0	2	−1	−2	0	3	2	5	.....	15
−3	−1	−1	−1	1	−3	−3	−1	2	1	4	.....	10
−5	−2	−2	−2	0	−4	−5	−3	1	0	3	.....	5
−6	−3	−4	−2	−1	−5	−6	−4	−1	−1	2	.....	0
6	7	7	6	8	7	8	9	12	11	12	.....	*M*
43	60	82	157	162	116	63	70	33	30	20	.....	*N*
4.0	3.0	3.5	2.8	3.1	3.9	4.7	4.3	4.2	4.2	3.2	.....	σ

Table 92

Lying Systolic Blood Pressure
(mm. Hg)

AGE IN YEARS 7	8	9	10	11	12		SS
120	118	120	123	115	122	....	100
117	116	118	121	114	120	....	95
114	114	116	118	112	118	....	90
112	112	113	116	111	117	....	85
110	110	111	114	109	115	....	80
108	108	109	112	108	113	....	75
105	105	107	109	107	111	....	70
103	103	105	107	105	109	....	65
101	101	102	105	104	108	....	60
98	99	100	102	102	106	....	55
96	97	98	100	101	104	....	50
94	95	96	98	100	102	....	45
91	93	94	95	98	100	....	40
89	91	91	93	97	99	....	35
87	89	89	91	95	97	....	30
85	87	87	89	94	95	....	25
82	84	85	86	93	93	....	20
80	82	83	84	91	91	....	15
78	80	80	82	90	90	....	10
75	78	78	79	88	88	....	5
73	76	76	77	87	86	....	0
96	97	98	100	101	104	....	*M*
26	30	37	73	42	44	....	*N*
7.7	6.9	7.6	7.5	4.6	5.9	....	σ

Table 93

Lying Diastolic Blood Pressure (mm. Hg)

Age in years 7	8	9	10	11	12	SS
9	11	20	37	26	31	100
14	16	24	40	29	34	95
19	21	28	43	33	38	90
24	26	32	46	37	41	85
29	31	37	49	40	44	80
34	36	41	52	44	49	75
39	41	45	55	48	51	70
44	46	49	58	51	55	65
49	51	53	61	55	58	60
54	56	57	64	59	62	55
59	61	61	67	62	65	50
64	66	65	70	66	69	45
69	71	69	73	70	72	40
74	76	73	76	73	76	35
79	81	77	79	77	79	30
84	86	81	82	81	83	25
89	91	85	85	84	86	20
94	96	89	88	88	90	15
99	101	93	91	92	93	10
104	106	97	94	95	97	5
109	111	101	97	99	100	0
59	61	61	67	62	65	*M*
25	28	30	67	39	39	*N*
17.7	16.9	13.6	9.9	12.7	11.8	σ

Table 94

Lying Pulse Rate (heartbeats per minute)

Age in years 7	8	9	10	11	12	13	SS
59	59	57	54	51	57	41	100
62	62	60	57	54	60	45	95
65	65	62	60	57	62	49	90
68	67	65	63	60	65	53	85
71	70	68	66	63	68	57	80
74	73	71	69	66	71	61	75
77	76	73	72	69	73	65	70
80	79	76	75	72	76	69	65
83	81	79	78	75	79	73	60
86	84	81	81	78	81	77	55
89	87	84	84	81	84	81	50
92	90	87	87	84	87	85	45
95	93	90	90	87	89	89	40
98	95	92	93	90	92	93	35
101	98	95	96	93	95	97	30
104	101	98	99	96	98	101	25
107	104	100	102	99	100	105	20
110	107	103	105	102	103	109	15
113	109	106	108	105	106	113	10
116	112	108	111	108	108	117	5
119	115	111	114	111	111	121	0
89	87	84	84	81	84	81	*M*
52	69	66	53	35	22	15	*N*
10.4	9.3	9.0	10.4	10.3	8.9	13.4	σ

Table 95

Standing Systolic Blood Pressure
(mm. Hg)

Age in Years 7	8	9	10	11	12		SS
128	130	124	129	122	121	....	100
125	127	122	127	121	120	....	95
122	124	120	125	119	118	....	90
119	120	118	123	118	117	....	85
116	117	116	121	116	115	....	80
113	114	114	119	115	114	....	75
110	111	112	117	113	112	....	70
107	108	110	115	112	111	....	65
104	104	108	113	110	109	....	60
101	101	106	111	109	108	....	55
98	98	104	109	107	106	....	50
95	95	102	107	106	105	....	45
92	92	100	105	104	103	....	40
89	88	98	103	103	102	....	35
86	85	96	101	101	100	....	30
83	82	94	99	100	99	....	25
80	79	92	97	98	97	....	20
77	76	90	95	97	96	....	15
74	72	88	93	95	94	....	10
71	69	86	91	94	93	....	5
68	66	84	89	93	91	....	0
98	98	104	109	107	106	....	*M*
26	67	31	73	42	43	....	*N*
9.6	10.5	7.8	7.1	5.6	5.8	....	σ

Table 96

Standing Diastolic Blood Pressure
(mm. Hg)

Age in Years 7	8	9	10	11	12		SS
18	13	19	47	40	24	....	100
23	19	24	50	42	29	....	95
28	24	29	52	45	34	....	90
33	30	34	55	47	38	....	85
38	35	39	57	50	43	....	80
43	41	44	60	52	48	....	75
48	46	49	62	55	52	....	70
53	52	54	65	57	56	....	65
58	57	59	67	60	61	....	60
63	63	64	70	63	66	....	55
68	68	69	72	65	70	....	50
73	74	74	75	68	75	....	45
78	79	79	77	70	80	....	40
83	85	84	80	73	84	....	35
88	90	89	82	75	89	....	30
93	96	94	85	78	94	....	25
98	101	99	87	80	98	....	20
103	107	104	90	83	103	....	15
108	112	109	92	85	108	....	10
113	118	114	95	88	112	....	5
118	123	119	97	90	117	....	0
68	68	69	72	65	70	....	*M*
23	25	29	70	38	40	....	*N*
16.4	19.9	16.0	8.8	8.9	15.9	....	σ

Table 97

Standing Pulse Rate (beats per minute)

7	8	9	10	11	12	13		SS
			Age in Years					
66	76	77	72	58	74	59	.....	100
70	79	80	75	62	78	63	.....	95
74	82	83	79	67	81	68	.....	90
79	85	86	82	71	84	72	.....	85
83	88	89	85	76	88	77	.....	80
87	91	92	88	80	91	81	.....	75
91	94	95	92	85	95	86	.....	70
95	97	98	95	89	98	90	.....	65
99	100	101	98	94	101	95	.....	60
103	103	104	102	98	105	99	.....	55
107	106	107	105	103	108	104	.....	50
111	109	110	108	107	112	108	.....	45
115	112	113	112	112	115	113	.....	40
119	115	116	115	116	118	117	.....	35
124	118	119	118	121	122	122	.....	30
128	121	122	121	125	125	126	.....	25
132	124	125	124	129	129	131	.....	20
136	127	128	127	133	132	135	.....	15
140	130	131	130	138	135	149	.....	10
145	133	134	133	142	139	144	.....	5
149	136	137	136	147	142	149	.....	0
107	106	107	105	103	108	104	.....	*M*
52	67	62	47	35	26	15	.....	*N*
13.7	11.4	10.4	11.0	15.1	11.4	15.0	.....	σ

Table 98

Pulse Rate After Exercise
(beats per minutes—Schneider test)

7	8	9	10	11	12		SS
		Age in Years					
82	89	83	95	92	90	....	100
86	92	86	97	94	92	....	95
91	95	89	100	96	95	....	90
95	98	92	102	98	97	....	85
100	101	95	104	100	100	....	80
104	104	99	107	102	102	....	75
108	107	102	109	104	104	....	70
113	110	105	111	106	107	....	65
117	113	108	113	108	109	....	60
122	116	112	116	110	112	....	55
126	119	116	118	112	114	....	50
130	122	119	120	114	116	....	45
135	125	123	123	116	119	....	40
139	128	126	125	118	121	....	35
144	131	129	127	120	124	....	30
148	134	132	130	122	126	....	25
152	137	136	132	124	128	....	20
157	140	139	134	126	131	....	15
161	143	142	136	128	133	....	10
166	146	146	139	130	136	....	5
170	149	149	141	132	138	....	0
126	119	116	118	112	114	....	*M*
26	29	31	73	42	44	....	*N*
14.6	10.3	11.1	7.6	7.1	8.0	....	σ

Table 99

Breath-Holding after 2 Minutes
Running Exercise (seconds)

8	9	10	11	12	13		SS
		Age in Years					
33	36	36	35	37	34	....	100
31	34	34	33	35	32	....	95
29	32	32	31	33	30	....	90
27	29	30	29	31	28	....	85
25	27	28	27	29	26	....	80
23	25	26	25	27	24	....	75
21	23	23	23	24	22	....	70
19	21	21	21	22	20	....	65
17	18	19	19	20	18	....	60
15	16	17	17	18	16	....	55
13	14	15	15	16	14	....	50
11	12	13	13	14	12	....	45
9	10	11	11	12	10	....	40
7	7	9	9	10	8	....	35
5	5	7	7	8	6	....	30
3	3	5	5	6	4	....	25
1	1	2	3	3	2	....	20
0	0	0	1	1	0	....	15
..	..	..	0	0	..	....	10
..	..	..	..	..	..	....	5
..	..	..	..	..	..	....	0
13	14	15	15	16	14	....	*M*
64	64	75	52	36	17	....	*N*
6.7	7.4	7.1	6.8	7.1	6.5	....	σ

Table 100

Flack Breath-Holding
(seconds)

Age in Years 7	8	9	10	11	SS
18.1	20.0	20.1	35.1	27.0	100
16.7	18.7	18.9	32.3	25.1	95
15.3	17.4	17.7	29.5	23.2	90
13.9	16.1	16.5	26.7	21.3	85
12.5	14.8	15.3	23.9	19.4	80
11.1	13.5	14.1	21.1	17.5	75
9.7	12.2	12.9	18.3	15.6	70
8.3	10.9	11.7	15.5	13.7	65
6.9	9.6	10.5	12.7	11.8	60
5.5	8.3	9.3	9.9	9.9	55
4.1	7.0	8.1	7.1	8.0	50
2.7	5.7	6.9	4.3	6.1	45
1.5	4.4	5.7	1.5	4.2	40
1.5	3.1	4.5	1.5	2.3	35
1.5	2.0	3.3	1.5	1.4	30
1.0	1.5	2.1	1.0	1.0	25
1.0	1.0	1.5	1.0	1.0	20
1.0	1.0	1.0	1.0	1.0	15
0.5	0.5	0.5	0.5	0.5	10
0.5	0.5	0	0.5	0.5	5
0	0	0	0	0	0
4.1	7.0	8.1	7.1	8.0	*M*
19	34	51	43	31	*N*
4.69	4.25	3.98	9.42	6.34	σ

Table 101

Five-Minute Step Test (beats for three 30-sec. periods)
(Sum of 3 pulse rates 1′-1′30″, 2′-2′30″, 3′-3′30″ after exercise)

Age in Years 7	8	9	10	11	12	13	SS
232	223	227	223	198	207	255	0
226	218	222	218	195	203	248	5
221	212	216	213	191	199	240	10
215	207	211	208	187	196	233	15
210	201	205	203	184	192	226	20
204	196	200	198	180	188	218	25
198	190	195	193	176	185	211	30
193	185	189	188	173	181	203	35
187	179	184	183	169	178	196	40
182	174	178	178	165	174	188	45
176	168	173	173	162	170	181	50
170	163	168	168	158	167	173	55
165	157	162	163	154	163	166	60
159	152	157	158	150	160	158	65
154	146	151	153	147	156	151	70
148	141	146	148	143	152	144	75
142	135	141	143	139	149	136	80
137	130	135	138	136	145	129	85
131	124	130	133	132	142	121	90
126	119	124	128	128	138	114	95
120	113	119	123	125	134	107	100
176	168	173	173	162	170	181	*M*
19	24	23	25	13	9	6	*N*
18.8	18.3	18.1	16.9	12.2	12.0	24.7	σ

Table 102

Vital Capacity (cubic inches)

Age in Years 7	8	9	10	11	12	13		SS
149	164	167	170	222	254	260	.....	100
144	159	163	166	214	246	252	.....	95
139	153	159	163	206	239	244	.....	90
133	147	154	159	198	231	236	.....	85
128	141	150	156	190	224	228	.....	80
123	135	146	152	182	217	220	.....	75
117	129	142	149	175	209	212	.....	70
112	123	137	145	167	202	204	.....	65
107	118	133	142	159	194	196	.....	60
101	112	129	138	151	187	188	.....	55
96	106	125	135	143	180	180	.....	50
91	101	120	131	135	172	172	.....	45
85	95	116	128	127	165	164	.....	40
80	89	112	124	119	157	156	.....	35
75	84	108	121	111	150	148	.....	30
69	78	103	117	103	143	140	.....	25
64	72	99	114	95	135	132	.....	20
59	66	95	110	87	128	124	.....	15
53	60	91	107	79	120	116	.....	10
48	54	86	103	71	113	108	.....	5
43	48	82	100	63	106	100	.....	0
96	106	125	135	143	180	180	.....	*M*
52	71	67	49	37	26	19	.....	*N*
17.8	19.4	14.2	11.8	26.7	24.6	26.8	.....	σ

Table 103

Vital Capacity Residual (cubic inches)

Age in Years 8	9	10	11	12	13		SS
94.18	79.07	94.80	80.90	97.24	65.78	....	100
87.70	73.62	86.62	73.08	88.67	59.22	....	95
81.22	68.17	78.44	65.26	80.10	52.64	....	90
74.24	62.72	70.26	57.44	71.53	46.06	....	85
68.26	57.27	62.08	49.62	62.96	39.48	....	80
61.78	51.82	53.90	41.80	54.39	32.90	....	75
55.30	46.37	45.72	33.98	45.82	26.32	....	70
48.82	40.92	37.54	26.16	37.25	19.74	....	65
42.34	35.47	29.36	18.34	28.68	13.16	....	60
35.86	30.02	21.18	10.52	20.11	6.48	....	55
29.38	24.57	13.00	2.70	11.54	0	....	50
22.90	19.12	4.82	— 5.12	2.97	— 6.58	....	45
16.42	13.67	— 3.36	—12.94	— 5.60	—13.16	....	40
9.94	8.22	—11.54	—20.76	—14.17	—19.74	....	35
3.46	2.77	—19.72	—28.58	—22.74	—26.32	....	30
— 3.02	— 2.68	—27.90	—36.40	—31.31	—32.90	....	25
— 9.50	— 8.13	—36.08	—44.22	—39.88	—39.48	....	20
—15.98	—13.58	—44.26	—52.04	—48.45	—46.06	....	15
—22.46	—19.03	—52.44	—59.86	—57.02	—52.64	....	10
—28.94	—24.48	—60.62	—67.68	—65.59	—59.22	....	5
—35.42	—29.93	—68.80	—75.50	—74.16	—65.78	....	0
29.38	24.57	13.00	2.70	11.54	0	....	*M*
64	58	60	50	26	16	....	*N*
21.589	18.183	27.271	26.057	28.555	21.938	....	σ

Table 104

Maximum Expiratory Blow (mm. Hg)

Age in Years: 7	8	9	10	11	12	13	SS
149	159	158	171	187	221	206	100
141	152	151	163	179	210	198	95
134	144	144	155	170	198	189	90
126	135	137	147	162	186	181	85
118	127	130	139	154	175	173	80
111	120	123	131	146	165	165	75
103	112	116	123	137	152	156	70
95	104	108	115	129	141	148	65
87	96	100	107	121	130	140	60
80	88	93	99	112	118	131	55
72	80	86	91	104	107	123	50
64	72	79	83	96	96	115	45
57	64	72	75	87	84	106	40
49	57	64	67	79	73	98	35
41	49	57	59	71	61	90	30
34	41	50	51	63	51	82	25
26	33	43	43	54	39	73	20
18	25	36	35	46	28	65	15
10	18	28	27	38	17	57	10
3	10	21	19	29	5	48	5
0	2	14	11	21	0	40	0
72	80	86	91	104	107	123	*M*
23	70	52	53	32	8	7	*N*
25.8	26.3	24.1	26.5	27.7	37.7	27.6	σ

Table 105

R Wave of the ECG (mm.)

Age in Years: 6	7	8	9	10	11	12	SS
51.5	52.9	49.7	51.5	48.4	50.2	52.9	100
49.1	50.4	47.4	49.1	46.5	47.9	50.4	95
46.6	47.9	45.2	46.7	44.5	45.6	48.0	90
44.2	45.4	42.9	44.3	42.6	43.4	45.6	85
41.8	42.9	40.7	41.9	40.6	41.1	43.1	80
39.4	40.3	38.4	39.5	38.6	38.8	40.7	75
36.9	37.8	36.1	37.1	36.8	36.5	38.2	70
34.5	35.3	33.9	34.8	34.7	34.2	35.9	65
32.1	32.8	31.6	32.4	32.8	32.0	33.3	60
29.6	30.3	29.4	30.0	30.8	29.7	30.9	55
27.2	27.7	27.1	27.6	28.8	27.4	28.5	50
24.8	25.2	24.9	25.2	26.9	25.1	26.0	45
22.3	22.7	22.6	22.8	24.9	22.8	23.6	40
19.9	20.2	20.4	20.4	23.0	20.6	21.1	35
17.5	17.7	18.1	18.0	21.0	18.3	18.7	30
15.0	15.1	15.0	15.6	19.0	16.0	16.3	25
12.6	12.6	13.6	13.2	17.1	13.7	13.8	20
10.2	10.1	11.4	10.9	15.1	11.4	11.4	15
7.8	7.6	9.1	8.5	13.2	9.2	8.9	10
5.3	5.1	6.9	6.1	11.2	6.9	6.5	5
2.9	2.5	4.6	3.7	9.2	4.6	4.1	0
27.28	27.74	27.14	27.59	28.84	27.40	28.47	*M*
9	46	76	68	51	35	20	*N*
8.10	8.40	7.51	7.97	6.54	7.59	8.14	σ

Table 106

T Wave of ECG (mm.)

Age in Years 6	7	8	9	10	11	12	13		SS
14.7	17.6	17.1	18.8	19.0	20.7	23.0	13.5	...	100
14.0	16.7	16.2	17.8	18.0	19.6	21.8	12.9	...	95
13.2	15.7	15.4	16.9	17.0	18.6	20.4	12.3	...	90
12.5	14.8	14.5	15.9	16.0	17.5	19.1	11.7	...	85
11.7	13.8	13.6	15.0	15.0	16.4	17.8	11.1	...	80
11.0	12.9	12.8	14.0	14.0	15.3	16.5	10.5	...	75
10.3	12.0	11.9	13.0	13.1	14.2	15.2	9.9	...	70
9.5	11.0	11.0	12.0	12.1	13.2	13.8	9.3	...	65
8.8	10.0	10.2	11.1	11.1	12.1	12.5	8.7	...	60
8.0	9.1	9.3	10.2	10.1	11.0	11.2	8.1	...	55
7.3	8.2	8.4	9.2	9.2	9.9	9.9	7.5	...	50
6.6	7.3	7.6	8.2	8.2	8.8	8.6	6.9	...	45
5.8	6.3	6.7	7.3	7.2	7.8	7.3	6.3	...	40
5.1	5.4	5.8	6.3	6.2	6.7	6.0	5.7	...	35
4.3	4.4	4.9	5.4	5.2	5.6	4.7	5.1	...	30
3.6	3.5	4.0	4.4	4.2	4.5	3.4	4.5	...	25
2.9	2.6	3.2	3.4	3.3	3.4	2.1	3.9	...	20
2.1	1.7	2.3	2.5	2.3	2.4	0.8	3.3	...	15
1.4	0.7	1.5	1.5	1.3	1.3	0	2.7	...	10
0.6	0	0.6	0.6	0.3	0.2	..	2.1	...	5
0	..	0	0	0	0	..	1.5	...	0
7.30	8.20	8.42	9.19	9.15	9.92	9.92	7.49	...	M
11	48	78	70	53	36	20	15	...	N
2.48	3.14	2.90	3.20	3.29	3.60	4.36	1.99	...	σ

Table 107

Systolic Amplitude of Brachial Pulse Wave—Heartograph (cm.)

Age in Years 6	7	8	9	10	11	12	13	14	15	16	17		SS
1.10	1.16	1.27	1.22	1.46	1.51	1.60	1.85	1.82	1.99	1.82	1.96	...	100
1.05	1.11	1.20	1.17	1.39	1.44	1.51	1.76	1.73	1.89	1.74	1.88	...	95
1.00	1.06	1.14	1.12	1.32	1.38	1.43	1.66	1.65	1.80	1.66	1.81	...	90
0.95	1.00	1.07	1.06	1.25	1.31	1.34	1.57	1.56	1.71	1.59	1.74	...	85
0.90	0.95	1.01	1.00	1.18	1.24	1.26	1.48	1.47	1.62	1.51	1.67	...	80
0.84	0.90	0.95	0.95	1.11	1.17	1.18	1.39	1.39	1.53	1.43	1.60	...	75
0.79	0.85	0.88	0.89	1.04	1.10	1.09	1.30	1.30	1.43	1.36	1.53	...	70
0.74	0.79	0.82	0.84	0.97	1.03	1.01	1.20	1.21	1.34	1.28	1.46	...	65
0.69	0.74	0.75	0.78	0.90	0.96	0.92	1.11	1.12	1.24	1.20	1.39	...	60
0.64	0.69	0.69	0.72	0.83	0.89	0.84	1.02	1.04	1.16	1.12	1.32	...	55
0.58	0.64	0.63	0.67	0.76	0.82	0.76	0.93	0.95	1.07	1.05	1.24	...	50
0.53	0.58	0.56	0.61	0.69	0.75	0.67	0.84	0.86	0.97	0.97	1.17	...	45
0.48	0.53	0.50	0.56	0.62	0.68	0.59	0.74	0.78	0.88	0.89	1.10	...	40
0.43	0.48	0.43	0.50	0.55	0.62	0.50	0.65	0.69	0.79	0.82	1.03	...	35
0.38	0.43	0.37	0.44	0.48	0.55	0.42	0.56	0.60	0.70	0.74	0.96	...	30
0.32	0.37	0.31	0.39	0.41	0.48	0.34	0.47	0.52	0.61	0.66	0.89	...	25
0.27	0.32	0.24	0.33	0.34	0.41	0.25	0.38	0.43	0.51	0.58	0.82	...	20
0.22	0.27	0.18	0.28	0.27	0.34	0.17	0.28	0.34	0.42	0.51	0.75	...	15
0.17	0.22	0.11	0.22	0.20	0.27	0.08	0.19	0.26	0.33	0.43	0.68	...	10
0.12	0.16	0.05	0.16	0.13	0.20	0	0.10	0.17	0.24	0.35	0.61	...	5
0.06	0.11	0	0.11	0.06	0.13	...	0.01	0.08	0.15	0.28	0.54	...	0
0.584	0.637	0.626	0.668	0.760	0.823	0.755	0.927	0.951	1.066	1.047	1.245	...	M
14	54	81	72	58	47	61	66	68	32	32	20	...	N
0.173	0.175	0.214	0.188	0.233	0.231	0.280	0.307	0.289	0.306	0.257	0.235	...	σ

Table 108

Area of Brachial Pulse Wave (sq. cm.)

AGE IN YEARS												
7	8	9	10	11	12	13	14	15	16	17		SS
.29	.41	.41	.40	.40	.43	.54	.59	.76	.69	.80	...	100
.28	.39	.39	.38	.38	.40	.52	.55	.72	.66	.76		95
.26	.36	.36	.36	.36	.38	.49	.52	.68	.62	.73	..	90
.25	.34	.34	.34	.34	.36	.46	.49	.63	.59	.69	.....	85
.24	.31	.31	.32	.31	.34	.43	.46	.59	.55	.65	....	80
.22	.28	.29	.30	.29	.31	.40	.43	.55	.52	.61	.....	75
.21	.26	.26	.28	.27	.29	.37	.40	.50	.49	.57	....	70
.19	.23	.24	.26	.25	.27	.34	.37	.46	.45	.54	.....	65
.18	.21	.21	.23	.23	.24	.31	.33	.42	.42	.50	.....	60
.16	.18	.19	.21	.21	.22	.28	.30	.38	.38	.46	.....	55
.15	.16	.16	.19	.18	.20	.26	.27	.33	.35	.42	.....	50
.13	.13	.14	.17	.16	.18	.23	.24	.29	.32	.38	.....	45
.12	.11	.11	.15	.14	.15	.20	.21	.25	.28	.35	.....	40
.10	.08	.08	.13	.12	.13	.17	.18	.20	.25	.31	.....	35
.09	.06	.06	.11	.10	.11	.14	.14	.16	.21	.27	.....	30
.07	.03	.03	.09	.08	.08	.11	.11	.12	.18	.23	.....	25
.06	0	.01	.07	.05	.06	.08	.08	.08	.15	.19	.....	20
.04	..	0	.04	.03	.04	.05	.05	.03	.11	.16	.....	15
.03	..	..	.02	.01	.01	.02	.02	0	.08	.12	.....	10
.02	..	..	0	0	0	0	0	..	.04	.08	.....	5
0	..	..	..	..	..	..	..	..	.01	.04	.....	0
.149	.157	.161	.192	.185	.198	.255	.271	.333	.350	.422	.....	*M*
54	80	72	58	48	60	66	68	32	32	20	.....	*N*
.049	.085	.084	.070	.072	.077	.097	.105	.143	.112	.128	.....	σ

Table 109

Obliquity Angle—Heartograph (degrees)

AGE IN YEARS													
6	7	8	9	10	11	12	13	14	15	16	17		SS
25	20	19	21	19	19	21	15	13	17	16	15	....	100
25	21	20	22	20	19	21	16	15	18	17	15	....	95
26	22	21	22	20	20	22	17	16	18	17	16	....	90
26	22	21	23	21	20	22	18	17	19	18	17	....	85
27	23	22	23	22	21	23	19	19	19	19	17	....	80
28	24	23	23	22	21	24	20	20	20	19	18	....	75
28	24	24	24	23	22	24	21	21	20	20	18	....	70
29	25	24	25	23	22	25	22	23	21	20	19	....	65
29	26	25	25	24	23	25	23	24	22	21	20	....	60
30	26	26	26	25	23	26	24	25	22	22	20	....	55
30	27	27	26	25	24	27	25	25	23	22	21	....	50
31	28	28	27	26	25	27	26	27	23	23	22	....	45
32	28	28	27	26	25	28	27	28	24	23	22	....	40
32	29	29	28	27	26	28	28	29	24	24	23	....	35
33	30	30	29	28	26	29	29	31	25	25	23	....	30
33	30	31	29	28	27	30	30	32	25	25	24	....	25
34	31	31	30	29	27	30	31	33	26	26	24	....	20
35	32	32	30	29	28	31	32	35	26	27	25	....	15
35	32	33	31	30	28	31	33	36	27	27	26	....	10
36	33	34	31	31	29	32	34	37	27	28	26	....	5
36	34	34	32	31	29	33	35	38	28	28	27	....	0
30	27	27	26	25	24	27	25	25	23	22	21	....	*M*
7	31	48	48	33	36	53	46	86	32	32	20	....	*N*
1.94	2.21	2.57	1.98	2.01	1.80	1.98	3.47	4.44	1.81	2.04	2.00	....	σ

APPENDIX C

A CASE STUDY: GROWTH AND TRAINING CHANGES IN A.H.

If one came across a 16-year-old high school boy who was an A student, played on the school football and basketball teams, was one of the top six golfers in the school, had been a member of Student Council since junior high school, and whose only fault, at least in the eyes of his parents, was that he was "very quiet at home and doesn't discuss problems with his parents," one would be excused a more than moderate interest in the genesis of such a young man. With respect to his ability in sports, two hypotheses might be entertained: first, that his parents had themselves shown above average competence in sports, and second, that his physical fitness, especially motor abilities, had proceeded along predetermined developmental lines and that he had been above average in these abilities at all age levels. That neither of these hypotheses can be sustained is shown in the following report of A.H., who first attended the Summer Sports-Fitness School in 1955 (age 9 years, 5 months), was a participant the following year (1956, age 10 years, 5 months), and was retested in 1960 (age 14 years, 3 months). While the profound changes in physique, motor performance, and circulatory-respiratory fitness exceed those normally observed, there is no reason to believe that the happy combination of circumstances underlying these changes could not be duplicated.

A.H. comes from an upper middle class home and has one sister, younger by three years, who at age 11 won a state title in swimming. His father had never played on a sports team, while his mother had been in school "the last one chosen," a situation which "really had an effect on me." The parents indicated a desire to see both the children enjoy experiences in sports to which they themselves had not been exposed. Evidence of this parental attitude is gained from the fact that A.H., prior to entering the Summer Sports-Fitness School, had played Little League baseball, had been a member of the YMCA for one year, and had attended a private swimming school.

The physical fitness data secured at the three age levels are shown in Tables 110 through 113. The T_1 data (1955) are those obtained at the beginning of the eight-week summer school, the T_2 data, those at the end, a span of approximately 14 months. The T_3 data (1960) were obtained independently of the Sports-Fitness school in connection with a follow-up study of former participants. The initial status and subsequent changes observed in physique, motor performance, and circulatory-respiratory fitness are outlined below.

Initial Status—T_1—Age 9 Years, 5 Months

Physique

A.H. was 6 pounds above average for a boy of his skeletal measurements (McCloy equation) and below the bottom of the standard score tables in fat, that is, excessive fat pads (sum of six skinfolds of 195 mm., —20 S.S.). He was well above average in general size (height 58.4 inches, 80 S.S.; weight 95.3 pounds, 82 S.S.). Expanded chest minus abdominal girth was +2.4 inches, equivalent to 28 S.S. The various foot measurements were exceedingly poor (Table 111), with

poor big toe angles in both feet, and a low arch angle, with indications of marked pronation, in the left foot (Plate XIV). The poor foot measurements were accompanied by a marked inability to use the feet and legs in power movements (standing broad jump, 49 inches, = 30 S.S.; vertical jump, 9 inches, = 34 S.S.). A

TABLE 110

Physique Changes in A.H.

	1955 (9-5)		1956 (10-7)		1960 (14-3)	
	RS	*SS*	*RS*	*SS*	*RS*	*SS*
Height (inches)	58.40	80	60.4	77	69.25	85*
Weight (pounds)	95.30	82	94.5	67	133.0	88*
Weight residual (McCloy) (pounds)	+5.60	..	+3.0	..	+7.97	..
Shoulder width / hip width	1.43	..	....	..	1.45	..
Chest depth / chest breadth	0.724	..	....	..	0.786	..
Thigh girth / knee width	5.37	..	....	..	4.93	..
Arm span / height	0.984	..	....	..	1.025	..
Height × 100 / 6 × transverse chest	1.140	..	....	..	1.180	..
Height / cube root of weight	12.94	47	13.27	40	13.59	62*
Bust height / height	0.475	..	....	..	0.461	..
Arm length / leg length	0.668	..	....	..	0.678	..
Foreleg length / thigh length	1.116	..	....	..	1.213	..
Upper arm / arm length	1.137	..	....	..	1.072	..
Leg length / trunk length	1.783	..	....	..	1.704	..
Chest breadth (inches)	8.7	..	8.7	..	9.8	..
Chest depth (inches)	6.3	..	6.7	..	7.7	..
Shoulder width (inches)	13.1	..	13.3	..	15.2	..
Hip width (inches)	9.2	..	9.4	..	10.5	..
Abdominal girth (inches)	25.6	..	23.9	..	26.8	..
Chest girth, normal (inches)	26.5	..	27.0	..	30.4	..
Chest girth, expanded (inches)	28.0	..	28.8	..	32.9	..
Chest girth, deflated (inches)	25.2	..	26.0	..	29.6	..
Expanded chest girth minus abdom. girth (in.)	+2.4	28	+4.9	57	+6.1	75
Gluteal girth (inches)	30.5	..	29.6	..	33.5	..
Calf girth (inches)	11.7	..	11.8	..	13.0	..
Biceps girth (inches)	9.1	..	8.9	..	10.4	..
Thigh girth (inches)	18.8	..	18.1	..	18.8	..
Skin-fold Fat Measures						
Cheeks (mm.)	19	..	17	..	18	..
Abdomen (mm.)	27	..	19	..	17	..
Hips (mm.)	27	..	21	..	14	..
Gluteals (mm.)	40	..	31	..	33	..
Front thigh (mm.)	39	..	21	..	23	..
Rear thigh (mm.)	38	..	24	..	30	..
Total fat (mm.)	190	(−20)	133	(35)	135	..

* 13-year-old tables.

protuberant abdomen, not uncommon in boys of this age, was noted from the somatotype photo (Plate XIII).

Motor Performance

A.H. was above average in tests of static strength and flexibility. The power tests involving use of the legs were well below average, while A.H. was unable to support the body weight in either chinning or dipping. He was average in 600-yard run time, and below average in all-out endurance hops (270 hops, = 44 S.S.).

Circulatory-Respiratory Tests

A.H. was below average in every test with the exception of post-exercise breath-holding (16 seconds, = 55 S.S.).

The instructors noted in their reports that A.H. sometimes sought attention by "fooling around," that he did not assert himself, "perhaps because of lack of ability," and that he was not particularly a leader. He appeared to adjust well to the program, however, and was considered, in general, quiet and attentive to instruction.

Following the normal procedure, A.H.'s parents were interviewed during the fall, and the results of the summer testing and training discussed. It was pointed out that he needed exercises for the feet and legs, endurance training, and special attention to his abdominal region which was moderately fat and protuberant. An effort was made during the following six months to bring about the specific improvements indicated, with formal training sessions once each week on Saturday morning and instruction in a program of training to be carried out at home. A series of corrective exercises for the feet was learned, and considerable running (outdoors, in the gymnasium, and on the treadmill), jumping and muscular endurance exercises were included in the program. A.H. was tested again the following summer, at which time marked changes in physique, motor performance, and circulatory-respiratory fitness were observed (Tables 110 to 113).

TABLE 111

Changes in Foot Measurements (A.H.)

	1955 (9-5)		1956 (10-7)		1960 (14-3)	
	RS	*SS*	*RS*	*SS*	*RS*	*SS*
Great toe angle, left (degrees)	26.5	6	19.9	34	27.0	0*
Great toe angle, right (degrees)	21.5	29	17.2	51	24.5	15*
Arch angle, left (degrees)	21.0	23	54.2	74	54.5	68*
Arch angle, right (degrees)	43.5	57	52.3	68	55.0	70*
Scaphoid deviation, left (mm.)	6.3	55	10.9	39	12.1	24
Scaphoid deviation, right (mm.)	6.9	52	8.5	46	7.0	43
Scaphoid height, left	19.0	22	21.0	35	36.0	17
Scaphoid height, right	23.0	28	26.0	40	40.0	33
Height of internal malleolus, left (cm.)	6.5	43	6.0	39	7.3	28
Height of internal malleolus, right (cm.)	6.1	39	7.1	48	7.4	35
Height of external malleolus, left (cm.)	6.1	45	6.9	53	6.8	53
Height of external malleolus, right (cm.)	6.7	50	7.1	55	7.0	53

* 13-year-old tables.

TABLE 112

Changes in Motor Performance (A.H.)

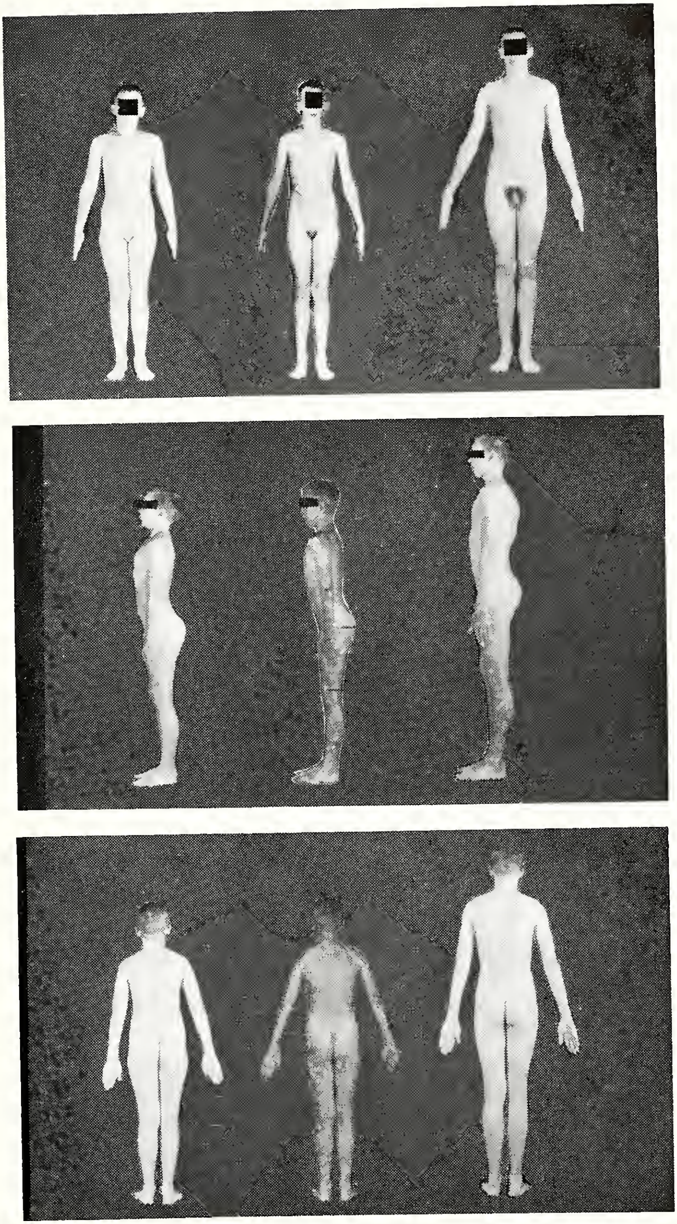
	1955 (9-5)		1956 (10-7)		1960 (14-3)	
	RS	*SS*	*RS*	*SS*	*RS*	*SS*
Agility						
60-yard dash (seconds)	10.6	56	9.9	70	....	..
Illinois agility run (seconds)	23.0	48	21.5	53	18.0	67
Visual reaction time (seconds)	0.367	63	0.358	61	0.284	70*
Auditory reaction time (seconds)	0.367	58	0.357	59	0.259	68*
Flexibility						
Trunk forward bending (inches)	6.65	77	9.4	52	4.3	100*
Backward extension (inches)	13.60	60	14.4	52	18.9	77*
Dynamometer Strength						
Left grip (pounds)	32	57	56	92	78	61
Right grip (pounds)	41	68	60	92	104	75
Back (pounds)	178	76	200	82	276	65
Legs (pounds)	180	59	300	95	332	62
Total (pounds)	431	70	616	98	790	67
Strength/weight	4.74	52	6.41	67	5.94	61
Power						
Standing broad jump (inches)	49	30	68	75	82	100*
Vertical jump (inches)	9.0	34	13.5	74	19.0	100*
Muscular Endurance						
Chins to bar (number)	0	0	0.5	30	3.5	23
Dips on bar (number)	0	0	2.5	55	6.0	38
All-out hops (number)	270	44	729	72	....	..
Floor push-ups (number)	15	70	9	53	20	75*

NOTE.—Standard scores entered in this table as "100" should be read as "100 or above."
* 13-year-old tables.

T_2—AGE 10 YEARS, 7 MONTHS

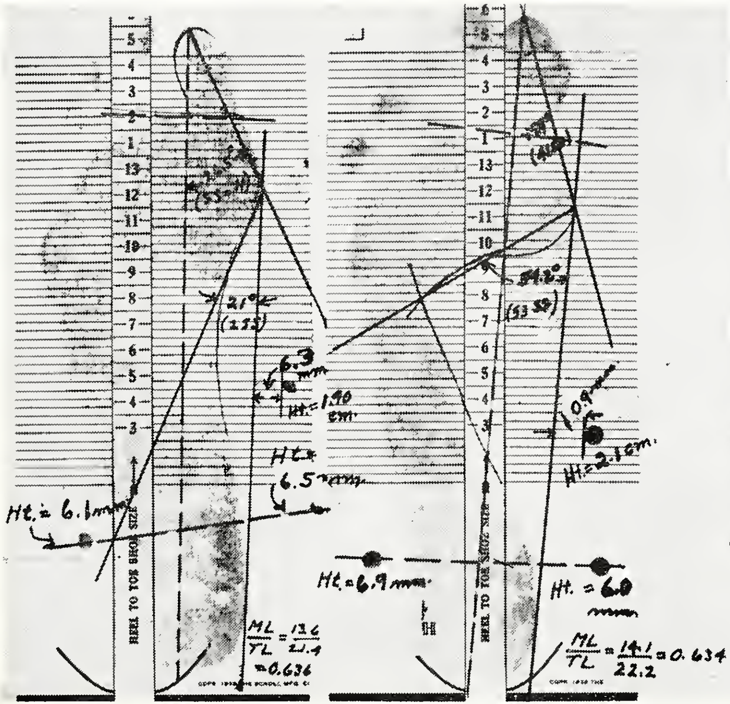
Physique

A.H. lost 0.8 pounds during the year (95.3 to 94.5), giving a residual of + 3.0 pounds or 3 pounds above average for boys with similar skeletal measurements (McCloy equation). The Baldwin-Wood age-height-weight tables give weights of 83.0 to 91.0 pounds for a comparable period. Much of this reversal in A.H.'s weight is attributable to decreases in superficial fat, the sum of six skinfolds decreasing from 190 mm. (—20 S.S.) to 133 mm. (+35 S.S.). The girth measurements for the gluteals, biceps, and thigh decreased also, as may readily be seen in the somatotype photo (Plate XIII). A shift in the direction of linearity may be noted in the increased reciprocal of the ponderal index (12.94 to 13.27). Abdominal girth decreased from 25.6 to 23.9 inches. A marked increase occurred in expanded chest minus abdominal girth (+2.4 inches, 28 S.S., to +4.9 inches, 57 S.S.). The alignment of the feet, especially the left, which had shown pronation

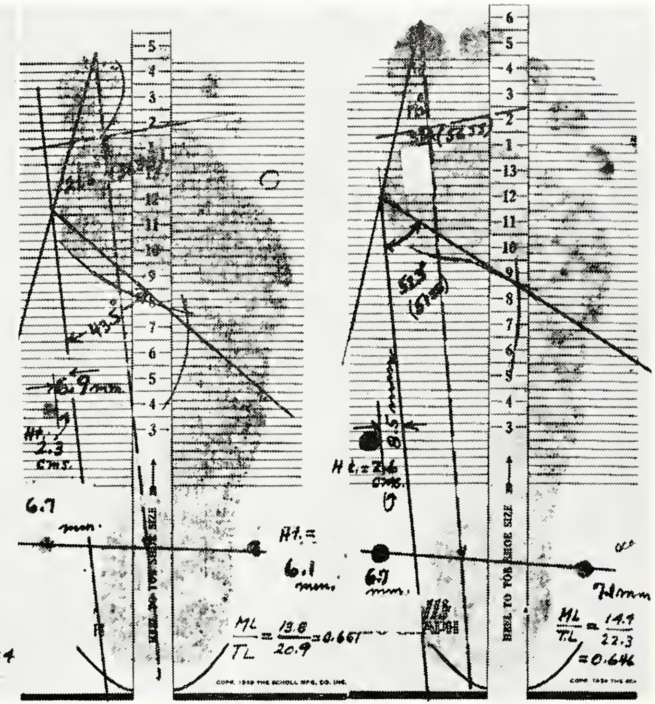


1955 1956 1960

PLATE XIII—Physique changes in A.H. associated with growth and training (see p. 44 and Appendix C).



(a) Changes in the left foot of A.H. (age 9-5, 10-5) associated with growth and training.



(b) Changes in the right foot of A.H. (age 9-5, 10-5) associated with growth and training.

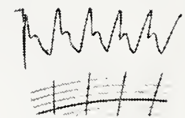
Plate XIV—Case study of changes in footprints.

TESTS	Units	RAW SCORES		STANDARD SCORES		SS % GAIN
		T_1	T_2	T_1	T_2	
ENDURANCE (Circulatory-Respiratory)						
Harvard 5' Step Test	Beats	0	160	0	41	41
600 Yd. Run	Secs.	169	135.5	32	79	47
4-Lap Swim	Secs.	127	116	-	-	-
ECG T-Wave	mm.	5.6	9.9	35	49	14
ECG R-Wave	mm.	12.9	26.8	-13	39	52
Heartograph Area	$cm.^2$	0.12	0.23	30	60	30
Heartograph Systolic Amplitude	cm.	0.46	0.98	34	62	28
Schneider Index	Points	4	-	40	-	-

BRACHIAL
SPHYGMOGRAM
(Heartograph)

8-4-55

BRACHIAL
SPHYGMOGRAM
(Heartograph)



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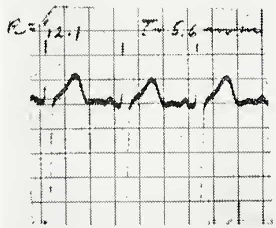
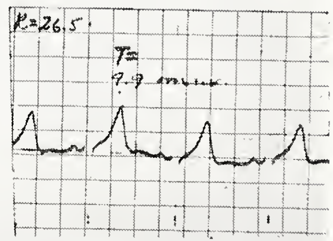


8-4-55

ELECTROCARDIOGRAPHIC
CHANGES



6-28-56

PLATE XV — Growth and training changes in cardiovascular condition of A.H. (age 9.5, 10.5) as reflected in endurance performance, brachial sphygmogram, and electrocardiogram.

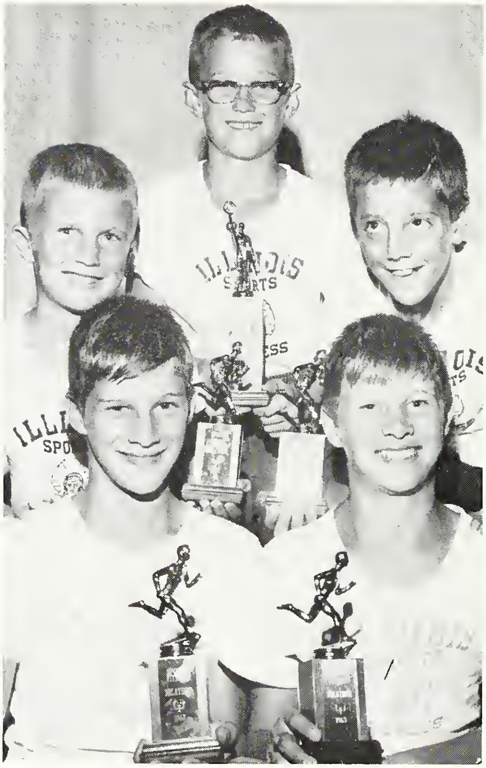


PLATE XVI—Sports-Fitness School: incentives.

TABLE 113

Changes in Cardiovascular-Respiratory Data (A.H.)

	1955 (9-5)		1956 (10-7)		1960 (14-3)	
	RS	*SS*	*RS*	*SS*	*RS*	*SS*
Brachial pulse wave area (sq. cm.)	0.12	42	0.23	60	0.27	50
Brachial pulse wave systolic amplitude (cm.)	0.46	32	0.98	66	1.13	60
ECG *T* wave (highest precordial) (mm.)	5.6	31	9.9	54	7.3	49*
Schneider index (units)	4	35	9	70	9	50
Vital capacity (cubic inches)	110	33	165	93	276	100*
Vital capacity residual (cubic inches)	−20.5	9	+26.7	68	+29.2	73*
Maximum expiratory blow (mm. Hg)	58	31	102	57	84	27*
Post-exercise breath-holding (seconds)	16	55	18	58	30	90*
600-yard run time (seconds)	169	48	135.5	68	....	..

NOTE.—Standard scores entered in this table as "100" should be read as "100 or above."
* 13-year-old tables.

earlier, was improved considerably (Plate XIV and Table 111). These changes were accompanied by improved function as reflected in the standing broad jump (49 inches, 30 S.S., to 68 inches, 75 S.S.) and vertical jump (9 inches, 34 S.S., to 13.5 inches, 74 S.S.).

Motor Performance

A.H. improved markedly in all tests of motor ability except the two flexibility tests, where some retrogression was shown. Exceptionally large gains were made in static strength (especially hands and legs), in leg power, and muscular endurance. The extraordinary improvement in functional use of the legs (standing broad jump, 45 S.S. gain; vertical jump, 41 S.S. gain; all-out hops, 28 S.S. gain; 600-yard run time, 20 S.S. gain) is undoubtedly attributable in some degree to the specific attention given the feet and legs in the follow-up training.

Circulatory-Respiratory Tests

Large gains were made in all tests of the cardiovascular and respiratory systems, both in the quiet state and associated with work (Plate XV). Unusually large improvements occurred in the brachial pulse wave (area, 0.12 sq. cm., 42 S.S., to 0.23 sq. cm., 60 S.S.; systolic amplitude, 0.46 cm., 32 S.S., to 0.98 cm., 66 S.S.), in the *T* wave of the electrocardiogram (5.6 mm., 31 S.S., to 9.9 mm., 54 S.S.), in the Schneider index (4, 35 S.S., to 9, 70 S.S.), in vital capacity (110 cubic inches, 33 S.S., to 165 cubic inches, 93 S.S.), and in 600-yard run time (169 seconds, 48 S.S., to 135.5 seconds, 68 S.S.).

T_3—AGE 14 YEARS, 3 MONTHS

Physique

The trend in the direction of linearity noted earlier had increased, and at age 14 years and 3 months A.H. was rated 2½ 3½ 4½, or an ectomesomorph in Sheldon's terminology. At this stage, he was 8 pounds above average in weight for boys with similar skeletal dimensions (McCloy), although the skin-fold fat

measures had remained at the T_2 level (135 mm. for six skin folds, 43 S.S.). This increase in actual weight compared with predicted weight is probably related to an increase in the density of the musculature. The expanded chest minus abdominal girth had increased still further to +6.1 inches (75 S.S.). All the girth measurements had increased except thigh girth, which was exactly the same as it had been five years earlier at T_1 (18.8 inches).

Analysis of the skeletal ratios shows a marked increase in the growth of the arms in relation to the legs, and to height, most of the increase occurring in the forearms. Thigh girth / knee width, an index of endomorphy or ponderosity, decreased due to the increase in knee width and the static nature of thigh girth. The lower segments of both limbs increased at a faster rate than the upper segments, while trunk length increased relatively faster than leg length.

Some retrogression was shown in the foot measurements (Table 111), especially in big toe angle, although the earlier improvements in arch angle had been retained.

Motor Performance

Moderate gains were shown in agility, while flexibility of the trunk in both flexion forward (9.4 inches, 52 S.S., at T_2, to 4.3 inches, 100 S.S.) and extension backward (14.4 inches, 52 S.S., at T_2, to 18.9 inches, 77 S.S.) was markedly increased. Moderate losses occurred in strategic strength, although these scores were still well above average. A.H. had increased his leg power considerably (standing broad jump, 68 inches, 75 S.S., at T_2, to 82 inches, 100 S.S.; vertical jump, 13.5 inches, 74 S.S., at T_2, to 19 inches, 100 S.S.), although he was still relatively weak in the shoulders (3.5 chins, 23 S.S.; 6 dips, 38 S.S.).

Circulatory-Respiratory Tests

Small retrogressions occurred in the brachial pulse wave and the *T* wave of the electrocardiogram, A.H. being average in these measures at this age. Vital capacity and breath-holding after exercise had both increased markedly (vital capacity, 276 cubic inches, 100 S.S.; post-exercise breath-holding, 30 seconds, 90 S.S.), although the force in maximum expiration had decreased from 102 mm., 57 S.S., T_2, to 84 mm., 27 S.S.

Summary

It seems apparent from the T_3 data that A.H. had increased his motor abilities in a rather extraordinary manner, but the cardiovascular tests do not reflect high levels of endurance training, which may indicate that even sports involving running (e.g., basketball, football) are inadequate in developing high levels of circulatory fitness. His parents reported that he trained in the basement at home with weights and skipping, that he had been pronounced "in excellent physical condition" at the medical examination prior to the last football season, and that, apart from callouses on the feet during the basketball season, his general health had been excellent. The interest of the parents in the physical growth and development of their son was again expressed in the hope that we would retest him at some convenient time. While it is difficult to isolate all the environmental factors influencing the remarkable transformation of A.H. from an overweight, physically inept boy to a linear, athletic type, the encouragement of his parents and the early exposure to laboratory testing, with its concomitant motivational impact, and endurance training of a kind and intensity not normally found in the public schools would probably claim high priority.

APPENDIX D

GRADUATE THESES COMPLETED IN THE SPORTS-FITNESS SCHOOL, UNIVERSITY OF ILLINOIS, URBANA, 1953–1962

1953

VERNON, WILLIAM R. *Physical Fitness Test Results and Norms for Fifth and and Sixth Grade Boys.* M.S. in Physical Education. 120 p.

1954

MATZ, GRACE ELAINE. *The Effect of Gymnastics on the Motor Fitness of Boys.* M.S. in Physical Education. 99 p.

OLSSEN, FREDERICK JESSE. *The Effects of Gymnastic Training on the Feet of Young Boys.* M. S. in Physical Education. 77 p.

ORBAN, WILLIAM A. R. *An Item Analysis of Temperament and Behavior Ratings of Young Boys.* M.S. in Physical Education. 61 p.

ROBY, FREDERIC B., JR. *The Effect of Training in Gymnastics on the Electrocardiogram.* M.S. in Physical Education. 63 p.

VOISARD, PAUL P. *Relationship between Body Build and Motor Educability of School Boys, Ages 10–13.* M.S. in Physical Education. 98 p.

WICKSTROM, ROBERT B. *Effects of Gymnastic Training on the Progressive Pulse Ratio Test of Boys.* M.S. in Physical Education. 64 p.

WRIGHT, JAMES N., JR. *The Effects of Gymnastic Training on the Heartographs of Young Boys.* M.S. in Physical Education. 96 p.

ZIMMERMAN, FORREST V. *The Effects of Tumbling and Trampoline Training on the Physiques of Young Boys.* M.S. in Physical Education. 57 p.

1955

DIORIO, LOUIS P. *The Effects of a Physical Training Program on the Cardio-Respiratory Fitness of Young Boys.* M.S. in Physical Education. 109 p.

1956

MCMAHON, WILLIAM J. *Organic Fitness with Relationship to Age in Young Boys.* M.S. in Physical Education. 67 p.

1957

BARRY, ALAN J. *A Factorial Study of Morphological and Performance Measurements in Pre-Pubescent Boys.* Ph.D. in Physical Education. 82 p.

KNOWLTON, RONALD G. *A Muscular Endurance Study of Pre-Adolescent Boys.* M.S. in Physical Education. 61 p.

LENT, ARNOLD L. *The Effects of Athletic Programs on the Strength of Young Boys in the Illinois Sports-Fitness Summer Day School.* M.S. in Physical Education. 216 p.

MAS, JOSEPH. *The Effect of Physical Activity on the Adiposity of Young Boys.* M.S. in Physical Education. 79 p.

ORBAN, WILLIAM A. R. *An Analysis of Measurement of Organic Efficiency of Boys.* Ph.D. in Physical Education. 199 p.

POWELL, JOHN T. *Effects of Rope Skipping on Pre-Pubescent Boys.* M.S. in Physical Education. 178 p.

SAKAMOTO, WAYNE Y. *The Relationship of Children's Heart Size with Height, Weight and Surface Area.* M.S. in Physical Education. 60 p.

1958

BELL, HARRY H. *The Effect of Gymnastics on the Cardiovascular Condition of Boys.* M.S. in Physical Education. 64 p.

BUTLER, CHARLES. *Improvement of the Strength Scores of Young Boys.* M.S. in Physical Education. 94 p.

CONNER, THEODORE W. *The Effects of Dietary Supplementary Feeding and Various Athletic Programs upon Strength.* M.S. in Physical Education. 53 p.

EYNON, ROBERT B. *Somatotype and Motor Fitness in Young Boys.* M.S. in Physical Education. 60 p.

HOLMES, RICHARD A. *The Effects of Various Methods of Training on Endurance and Cardiovascular Tests.* M.S. in Physical Education. 73 p.

HUPE, ANDRE S. *The Effects of Training and Supplementary Diet on the Cardiovascular Condition of Young Boys.* M.S. in Physical Education. 74 p.

MARSH, RICHARD L. *The Effects of a Bicycle Training and Muscular Conditioning Program on Cardiovascular and Endurance Components in Pre-Adolescent Boys.* M.S. in Physical Education. 117 p.

PATTEE, LAWRENCE L. *Effects of Developmental Activities on Pre-Pubescent Boys.* M.S. in Physical Education. 65 p.

SLUSAREK, ROBERT L. *Relationship of Heartometer Measurements to the 600 Yard Run.* M.S. in Physical Education. 73 p.

STABLEFORD, JAMES D. *Improving Upper Body Strength in Selected Boys.* M.S. in Physical Education. 69 p.

TILLMAN, KENNETH G. *The Effects of Dietary Supplements and Four Different Training Methods on Reaction Time and Agility.* M.S. in Physical Education. 63 p.

1959

DOROSCHUK, EUGENE V. *The Prediction of All-out Treadmill Running of Boys from Oxygen Intake Measures.* M.S. in Physical Education. 51 p.

LEAMING, T. W. *A Measure of Endurance of Young Speed Skaters.* M.S. in Physical Education. 43 p.

1960

ARAKI, CHARLES T. *The Effects of Medicine Ball Exercises on the Upper Body Development of Young Boys.* M.S. in Physical Education. 75 p.

BROWN, STANLEY R. *Factors Influencing Improvement in the Oxygen Intake of Young Boys.* M.S. in Physical Education. 75 p.

HAIG, PATRICIA. *A Comparison of the Results of a 7-Item Motor Fitness Test Carried Out on East London and American School Girls.* M.S. in Physical Education. 144 p.

HERRON, ROBERT E. *The Constancy of Physique in Adolescent Boys.* M.S. in Physical Education. 48 p.

JOHNSTONE, ROSEMARY. *A Comparative Study of the Physical Fitness of American and East London School Boys.* M.S. in Physical Education. 129 p.

1961

LARSON, CHARLES E. *The Effects of Weight Training on the Upper Body Development of Young Boys.* M.S. in Physical Education. 111 p.

OBERICHT, LEO F. *The Development of a Metrical System of Assessing the Body Type of Young Boys.* M.S. in Physical Education. 112 p.

1962

DOROSCHUK, EUGENE V. *The Relationship of Metabolic, Cardiovascular and Motor Fitness Tests to Endurance Running of Young Boys.* Ph.D. in Physical Education. 69 p.

PAPE, DONALD L. *Physique Ratios Related to Age in Boys 7–13 Years.* M.S. in Physical Education. 106 p.

SHERMAN, MICHAEL A. *Effects of Interval Running on the Endurance and Cardiovascular Condition of Selected Young Boys.* M.S. in Physical Education. 96 p.

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